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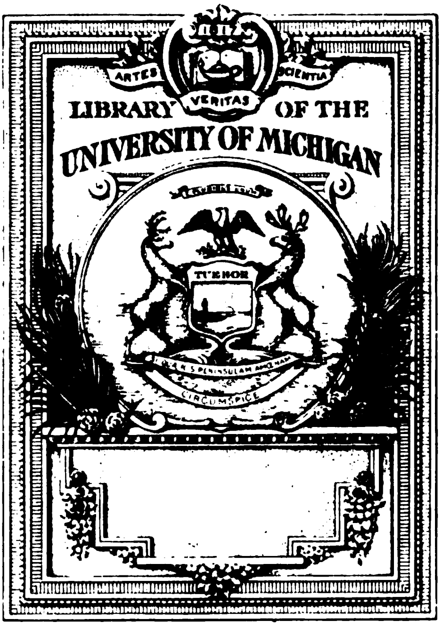
Annual report of the Director of the Agricultural Station ...



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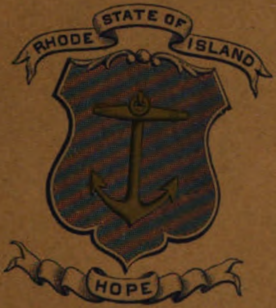

PART II
SIXTEENTH ANNUAL
REPORT.

FORMAL REPORT OF
THE BOARD OF MANAGERS
IS PART I.

COLLEGE CATALOGUE
IS PART III.

Kingston,

R.

State of Rhode Island and Providence Plantations.

SIXTEENTH ANNUAL REPORT

OF THE

RHODE ISLAND

AGRICULTURAL EXPERIMENT STATION, Kingston

1902-1903.

PART II.

OF THE

SIXTEENTH ANNUAL REPORT

OF THE

CORPORATION, BOARD OF MANAGERS

OF THE

Rhode Island College of Agriculture and Mechanic Arts,

MADE TO THE

GENERAL ASSEMBLY AT ITS JANUARY SESSION, 1904.

[Parts I. and III. of this Report — Report of President and Board of Managers and College Catalogue — are printed under separate covers]

PROVIDENCE, R. I.:
E. L. FREEMAN & SONS, PRINTERS TO THE STATE.
1904.

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OF THE

RHODE ISLAND

College of Agriculture and Mechanic Arts.

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EXPERIMENT STATION STAFF.

H. J. WHEELER, Ph. D[1]	Director and Chemist.
FRED W. CARD, M. S	Horticulturist.
COOPER CURTICE, D. V. S., M. D[2]	Biologist.
BURT L. HARTWELL, Ph. D	First Assistant Chemist.
GEORGE E. ADAMS, B. S	Assistant, Field Experiments.
ALFRED W. BOSWORTH, B. S	Second Assistant Chemist.
JAMES W. KELLOGG, B. S	Assistant Chemist.
A. E. STENE, M. S	Assistant Horticulturist.
NATHANIEL HELME	Meteorologist.
S. ALINE NYE	Stenographer and Accountant.
MARY G. SCHERMERHORN	Stenographer and Librarian.

[1] In charge of field experiments.

[2] In charge of poultry experiments.

The publications of the Station will be mailed free on request to anybody in Rhode Island interested in Agriculture. The Station desires the co-operation of the farmers of the State in the work of investigation, and any facts of special interest concerning animal or vegetable growth or disease are solicited. Visitors are always welcome. Railroad station, telegraph, express, and post-office—Kingston, Rhode Island.

General

LETTER OF TRANSMITTAL.

To His Excellency Lucius F. C. Garvin, Governor, and the Honorable the General Assembly of the State of Rhode Island, at its January Session, 1904.

KINGSTON, R. I., June 30, 1903.

I have the pleasure to present herewith, in compliance with the statute of the State and the Congressional act of March 2, 1887, the Report of the Director of the Rhode Island Agricultural Experiment Station for the year ending June 30, 1903.

Respectfully submitted,

For the Board of Managers,

J. V. B. WATSON,

President, Pro tem.

AGRICULTURAL EXPERIMENT STATION

OF THE

RHODE ISLAND COLLEGE OF AGRICULTURE AND MECHANIC ARTS.

KINGSTON, R. I., June 30, 1903.

HON. J. V. B. WATSON,

President pro tem. Board of Managers.

SIR:—I have the honor to transmit herewith the Sixteenth Annual Report of the Rhode Island Agricultural Experiment Station for the year ending June 30, 1903.

Respectfully yours,

H. J. WHEELER,

Director.

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DIRECTOR'S REPORT.

REPORT OF THE DIRECTOR.

H. J. WHEELER.

To J. V. B. Watson, Vice-President of the Board of Managers of the Rhode Island College of Agriculture and Mechanic Arts.

SIR:—In order to systematize this report, the work of the various divisions and the other subjects which come under consideration will be presented individually.

BIOLOGICAL DIVISION.

The work of the biological division has in the past year been in charge of Doctor Cooper Curtice. The chief lines of study have been the following:

(1) A study of the conditions affecting incubation, with special reference to the eggs of ordinary poultry.

(2) A study of the conditions affecting brooding, also the feeding of young chicks.

(3) Investigation to ascertain if the death of young chicks, having an affection of the lungs, was due to the presence of the bacillus of tuberculosis.

(4) A continuation of the study of the transmissibility and means of control of the "blackhead" (infectious *Entero-hepatitis.* Smith) disease of turkeys.

The work of this division, aside from correspondence, has been in connection with incubation and feeding, and will be fully outlined in this report or in subsequent papers.

Regarding the examination of the lungs of diseased chicks, it may be stated that as yet the specfic bacillus which is supposed to be the cause of tuberculosis has not been found, even though the chicks showed all of the symptoms which have in certain instances been claimed to be symptoms of tuberculosis.

So far as concerns the "blackhead" disease of turkeys, it was thought by some of the leading experts in the United States, as stated in the last annual report, that a turkey that had once been affected by the disease would, upon its recovery, produce eggs free from the organisms. It was further supposed that if the turkeys were removed from a given area for a year or more the organisms which caused the disease, and which might be present in the soil, would be entirely destroyed. Working upon this theory, the Station secured a number of turkey eggs in the spring of 1902 which were hatched under hens or in incubators. An attempt was made to rear the young turkeys upon soil where turkeys had not roamed for several years. Arrangements were made with Mr. Edwin Knowles, of Point Judith, to transfer these turkeys, when they reached a suitable age, to an island in the Great Salt Pond in South Kingstown, where no turkeys had been kept for a long period. It was hoped in this way to obtain animals, free from the "blackhead" disease, which could be used later in restocking portions of the State where no turkeys had been kept for at least a year or more. It was believed not only that the "blackhead" disease would be avoided in this way, but that some of the other difficulties connected with the rearing of turkeys might also be avoided to a certain extent. As the season advanced the young turkeys, which had been hatched upon the Station grounds began to die; and upon examination it was found that they had pronounced cases of the "blackhead" disease. From this it became evident that the disease is transmitted through the turkey egg, is conveyed by ordinary fowl, even though they themselves show no superficial indication of the disease, or that some other host carries the organism and transmits it to the young turkeys. Thus the problem, which seemed in the early spring of 1902 to be possibly easy of solution, was found to be far more complicated than was supposed. In the winter of 1902 and 1903, efforts were made to secure turkey eggs from Virginia and North Carolina, from sections where the "blackhead" disease was supposed not to exist. Unfortunately, however, chiefly owing to the prospective increased price of turkeys, it was absolutely impossible to obtain sufficient eggs from these sections, even notwithstanding that two entire counties in Virginia were canvassed for this purpose in our interest. It is planned now to secure, if possible, some turkeys from a region where the disease is supposed not to exist, so that uncontaminated eggs may be secured the coming year for experimental purposes. It is hoped to pursue the study of the question, with the hope of learning how the disease is transmitted, that is, whether through ordinary fowl or by other means; but doubtless several years will elapse before it can be hoped that definite light can be thrown upon this problem. With the hope of aiding in settling the question, experiments are now in progress to see if the "blackhead" disease of the turkey can be transmitted directly to young chicks. From what has been said it must be apparent to all that the problem is a most difficult and complex one, and the public should have patience and not expect the head of the biological division to arrive at an immediate solution of the problem. The details of all the various lines of work in which the division is engaged will be published from time to time, as the progress of the work may justify such a course.

HORTICULTURAL DIVISION.

The horticultural division is obliged to answer many inquiries in relation to insect pests, fungous diseases of plants, and general questions bearing upon horticultural work. The lines of experiment in progress are the following:

Apple Breeding.—A study of the influence of the choice of cions upon the productiveness and the year of chief fruitfulness.

Apple Maggot.—Further study of the habits of this insect, with attempts to discover methods of combating it.

Bush Fruits.—Observations upon fruiting habit, and effects of interpollination. Work in selection, crossing, and the growing of seedlings.

Corn Selection.—Experiments upon the influence of selection upon Indian corn.

Bean Selection.—Attempts to develop a hardier and more frost resisting type of beans.

Swamp Blueberry.—Experiments in propagation.

Stock, Influence of.—Observations upon the influence of stock upon the color of fruit, blooming period, and other characteristics.

Strawberries.—Continued work in selecting, crossing, and the growing of seedlings.

Asters.—A comparison of fall and spring sowing of aster seed.

Clover Selection.—An attempt to improve common red clover by selecting seed from vigorous and most desirable individual plants.

Influence of Protection of Vegetables and Strawberries.—Strawberries, lettuce, cauliflower, celery, and cucumbers are being grown under conditions of more or less complete protection by covering with the same kind of cloth used in connection with tobacco experiments in the Connecticut Valley.

Sterilization of Soil.—The influence of sterilization upon the growth of certain plants.

AGRICULTURAL FIELD EXPERIMENTS.

Rotation Experiments.—Six rotations of crops are in progress:

(1) A three-year rotation embracing clover, potatoes, and winter rye, using chemical manures only.

(2) A four-year rotation embracing clover, Indian corn, potatoes, and winter rye. This rotation is conducted with the use of stable manure and chemicals.

(3) A five-year rotation including Indian corn, potatoes, winter rye, grass, grass.

(4) A five-year rotation identical with the preceding one, excepting that common red clover seed is sown upon the rye field in March, so that, succeeding the winter rye, the land is in clover and

grass for the first year instead of in grass. The two five-year rotations are each conducted solely with chemical manures. It is hoped that a comparison of the two will, after the lapse of several years, indicate what advantage, if any, is derived upon the introduction of the common red clover.

(5) A five-year rotation embracing six crops as follows:

First year, clover;
Second year, potatoes;
Third year, winter rye for fodder or bedding, followed by Hubbard squashes;
Fourth year, early peas, followed by Swedish turnips;
Fifth year, oats seeded with clover.

Chemical manures only are used in this rotation.

(6) Six-year rotation. This rotation embraces Indian corn, potatoes, winter rye, clover and grass, grass, grass.

Three of the plots in this rotation are manured with stable manure and chemicals, and the other three solely with chemical manures. During the earlier years of the experiment comparisons were made of lime and chemicals with wood ashes and chemicals; but after continuing it for several years, and noticing no advantage from the wood ashes and chemicals over the lime and chemicals, the further continuance of this comparison was abandoned.

(7) Continuous growth of Indian corn by use of chemical manures. This is an experiment designed to see if Indian corn can be grown continuously upon the same land by the use of chemical manures. An acre of land is employed in this experiment, the field being divided into four sections. Upon one section crimson clover is sown at the last hoeing of the corn, and upon another winter rye is sown. The two other sections do not receive a "catch crop."

Special Grass Experiments.—(1) To determine the minimum amount of nitrogen in nitrate of soda required annually for the production of at least four tons of hay per acre.

(2) To determine the minimum amount of potash in muriate of potash required annually for the production of four tons of hay per acre.

(3) To determine the minimum amount of phosphoric acid in acid phosphate required annually for the production of four tons of hay per acre.

(4) Continuous growth of grass upon the same land by the use of chemical manures, in one instance by replowing and harrowing in the ordinary manner and in the other instance by breaking up the surface by harrowing and then plowing and preparing the soil by successive harrowings.

Phosphate Experiments.—This is a continuation of a trial of phosphoric acid in nine different kinds of material, as follows:

Dissolved boneblack.
Dissolved bone.
Acid phosphate (dissolved phosphate rock).
Fine ground bone.
Basic slag meal.
Floats (finely ground unacidulated phosphate rock).
Raw alumina phosphate.
Ignited aluminum phosphate (roasted Redondite).
Double superphosphate.

These trials are conducted upon both limed and unlimed soil, and during the season of 1903 sixteen different crops are being grown for the purpose of studying the feeding power of various plants for phosphoric acid.

Check on Rotation Experiments.—This consists of the continuation of experiments which have been in progress for several years for ascertaining whether or not excessive amounts of manure are being employed in connection with certain of the rotations.

Soda Experiments.—These are being conducted on forty-eight sixtieth-acre plots. The experiment was begun in 1894, and has been continued since without interruption. The plots are at present in grass, the object being to increase the amount of vegetable matter in the soil, and, by withholding potash from all of the plots, to still further reduce the amount of assimilable potash to such an extent as to make the soda more effective than otherwise, provided it exerts an influence upon the growth of plants. A paper bearing upon certain phases of the soda question is being prepared for publication, and will be issued in this report or in a subsequent bulletin.

Cowpeas.—A trial is being made the present season of forty-eight different varieties of cowpeas for the purpose of determining which are best suited to Rhode Island conditions. In connection with this work an attempt is being made to acclimate the Whip-poor-will cowpea so that it may produce seed in this climate.

Soil Test.—The soil test experiment which was begun in 1890 is this season devoted to grass and clover. It has been of much interest to note that the clover crop is a success only where a sufficient supply of potash has been used, even notwithstanding that all of the plots have been limed. It appears, therefore, that the application of potash is just as essential upon our Rhode Island soils for the success of clover as lime.

Special Nitrogen Experiment.—This is a continuation of an experiment, begun in 1890, for the purpose of making comparative tests of like amounts of nitrogen in nitrate of soda, sulfate of ammonia and dried blood. Winter rye occupies the plots the present season. The special study of the action of like amounts of nitrogen in sulfate of ammonia as compared with nitrate of soda is still being continued upon the permanent experimental plots Nos. 23, 25, 27, and 29. It should be remembered that about 200 different kinds of plants had been tested upon these plots already. Last year they were devoted entirely to soy beans, and this year to clover and grass. This experiment is furnishing at the present time one of the most striking illustrations of the necessity of using lime if the clover crop is to be a successful one. The experiment also shows the superiority of nitrate of soda to sulfate of ammonia upon our acid soil as a source of nitrogen for timothy.

Fungicides and Insecticides.—Comparative trials of bug death and other insecticides and fungicides are being conducted in connection with other experimental work.

Miscellaneous Work.—This involves trials of several new varieties of potatoes and other crops.

Vegetation Experiments in Pots.—These experiments are being conducted in large pots 18 inches in diameter, which are sunk in the ground to a depth of 24 to 26 inches, and also in small pots placed upon trucks so that they can be run under a shelter at night or when it rains. In the large pots a further study is being made of the comparative assimilability of nitrogen from several different sources, this work having been begun several years ago.

Inoculation Experiment.—This is an experiment for the purpose of ascertaining whether or not any practical benefit may be derived from inoculating soils, which are just being broken up for the first time, by introducing organisms from soils in good condition which have been under cultivation for many years.

CHEMICAL DIVISION.

The chief work of the chemical division consists in the analysis of commercial fertilizers and concentrated commercial feeding-stuffs in connection with the fertilizer and feeding-stuff inspection. Various chemicals used in connection with the horticultural, field, and pot vegetation experiments are also analyzed. It is hoped to make a further study of the composition of grass grown with various amounts of nitrogen, potash, and phosphoric acid. A study is being made, likewise, of the soils of the plots upon which phosphoric acid from various sources is being employed, with the hope of ascertaining what method of chemical analysis comes the nearest to telling the manurial needs of the soil as they are shown by means of an actual test with plants. It is hoped to continue the analysis of various plants grown with various proportions of potash and soda, for the purpose of ascertaining in what manner the use of soda has proved beneficial in connection with the growth of certain plants.

PUBLICATIONS.

There have been published during the year the following bulletins:

September, 1902, "Fowl Typhoid." 10 pp.
October, 1902, "The Forests of Rhode Island." 29 pp.
October, 1902, "Commercial Fertilizers." 16 pp.
January, 1903, "Further Experiments in Top-dressing Grass Land." 20 pp.
March, 1903, "Bush Fruits." 32 pp.
March, 1903, "The Soy Bean." 11 pp.
June, 1903, "Commercial Fertilizers," 19 pp.
June, 1903, "Commercial Feeding-Stuffs," 24 pp.

During the past winter the Station mailing list for Rhode Island has been revised and the names of non-residents of the State, excepting those connected with the experiment stations, who did not by letter or postal card request that the publications be continued, were all stricken from the list; yet, notwithstanding, an edition of 12,000 copies is required to meet the demands.

CORRESPONDENCE,

What was said in the last annual report in relation to the increase of correspondence has held true the past year. Large numbers of inquiries in relation to various agricultural matters are received from Rhode Island as well as from the entire eastern part of the United States, and many also from the Pacific coast. The demands in this line are so many at times as to interfere seriously with the other work of the Station. These inquiries, however, apparently come to the Station solely by reason of the fact that its work is highly appreciated and is widely recognized in the various States of the Union. The chief subjects of inquiry the last year have been regarding the treatment of soils, the use of fertilizers, the rearing of poultry, and the combating of insect pests and plant diseases.

LIBRARY.

During the year the current scientific periodicals of the Station have been suitably bound and the arrangement of the balance of the reports and bulletins of the various agricultural experiment stations of the United States for binding, which was begun the previous year, is completed; so that these publications are less likely to be lost, and will be much better preserved, than when left in the files in pamphlet form as had been the case since the establishment of the Station. A beginning has been made in preparing the publications of the Department of Agriculture for binding, and it is hoped that this also can be completed during the coming year. Great difficulty has been experienced in obtaining missing numbers of the various bulletins and reports of the agricultural experiment station. In this connecton it should be stated that numerous inquiries are being received at the Rhode Island Station for some of its earlier publications which are now out of print, and a reasonable price will be paid by the Station for the return of certain of the earlier bulletins and reports by persons who may not care to preserve them. The bulletins which are desired are indicated by a star in the summary to be found in the list of station publications which is inserted just before the title page and index to this volume.

ADDITIONS TO THE EQUIPMENT OF THE STATION.

During the past year few additions to the equipment of the horticultural division have been made, practically everything having been supplied the year before, which was necessary for the proper execution of the work. In connection with the biological division, several brooders have been added, improvements have been made in the poultry houses, over $400.00 worth of laboratory fittings and supplies have been secured to be used in the study of animal diseases, and the north laboratory of the Experiment Station building, which has recently been renovated, has been thoroughly fitted up with tables, cases, and equipment for work in the line just mentioned.

For the purpose of further facilitating the experimental work in the field, a new cutaway harrow and such other farm machinery and tools as were necessary have been added to the equipment. The addition to the "Plain" barn which was made during the past year has proved of inestimable value, and it has been of great assistance in conducting the work expeditiously and economically No imimportant additions have been made to the equipment of the chemical division for the past year. In the line of fittings for the Experiment Station office, a new and large case of drawers has been secured for holding the card index of the bulletins and reports of the Experiment Stations in the United States. This case is probably large enough to meet the needs of the Station for many years to come. In order that the half-tone cuts of the Station may be properly preserved, cases have also been built in which they can be systematically arranged and protected from injury. A case for the filing of the correspondence of the Station and an improved outfit for copying letters have also been introduced, thus facilitating in a considerable measure the conduct of the office work.

NEEDS OF THE STATION.

In presenting the needs of the Station at the present time it is necessary to call attention once more to the fact that the work of the biological division in incubating and rearing young chicks in the winter months is most seriously interfered with by the necessity of allowing the College to use the buildings for educational purposes during the continuance of the six-week course in poultry culture which begins early in January. The College should be provided with a suitable incubator house and with a proper house for brooding purposes, as well as with other space necessary for conducting educational work with poultry in the proper manner. The difficulty which the Station meets is not that it is not provided with suitable buildings for poultry work, for such have been provided without expense to the State; and it would seem that the State should at least supply the College with sufficient buildings so that it need not encroach upon the Experiment Station buildings at the time when they are most needed for legitimate experimental work.

Attention was called last year to the desirability of a further differentiation of College and Station work. Owing to the recent changes in the administration of the College, it has been too much to expect that this matter could receive due attention at once, but it is hoped that during the course of the coming year such adjustments and reorganizations may be effected as may prove of advantage not only to the Experiment Station but also to the College. Aside from the desired release of the Station poultry buildings by the authorities of the College, it is believed that the most pressing need, for which no provision has been made, is a suitable greenhouse where experiments with garden vegetables and with flowering plants can be conducted in a satisfactory manner. It is believed by the organized florists and gardeners of this State that such an equipment would place the Station in a way to be of material assistance to those industries, and certain of these organizations have already petitioned the Board of Managers of the College to ask the State for suitable structures of this kind. One or more of the assistants connected with the Experiment Station work could very profitably devote some portion of the winter months to experimental work under glass without material additional expense to the Station, and with but little, if any, direct cost to the State. It is hoped, therefore, that early provision for greenhouses will be made. It is nevertheless desirable, when such houses are furnished, that the College should likewise be provided with suitable greenhouse space for the purpose of education; for if not, the same tendency to encroach upon Experiment Station buildings for educational work will doubtless arise as in the case of the poultry buildings belonging to the Station. It must be obvious to all who are familiar with greenhouse management that careful experimental work cannot be conducted if the public generally and the students of the College are to have free access to the experimental houses at all times, for in some instances the temperature must be controlled within very narrow limits—a thing which is impossible if such houses are to be a common thoroughfare for the public.

THE STATION STAFF.

Doctor Curtice has remained in charge of the poultry investigations during the past year. Prof. F. W. Card has likewise remained in charge of the horticultural work. Owing to the resignation of Mr.

L. P. Sprague, B. S., of the University of Vermont, early in 1903, Mr. A. E. Stene, M. S., a graduate of Cornell University, was appointed to fill the vacancy. Mr. B. L. Hartwell, who has been assistant chemist to the State since 1891, and who had been given a leave of absence for a portion of the past two years, has received the degree of Doctor of Philosophy from the University of Pennsylvania, and permanently resumed his duties at the Station in June, 1903. The Station is to be congratulated upon the fact that few changes in the staff have occurred during the year, for nothing is more conducive to the value of experimental work than continued and unremitted efforts in definite and well chosen lines; which is rendered impossible by continued changes of policy which often follow changes in a Station staff.

ACKNOWLEDGMENTS.

It is once more my pleasant duty to express my appreciation of the cordial support of the Board of Managers and to thank the heads of divisions and their assistants and all others connected with the Station for their most hearty co-operation and for the careful attention devoted to their work. A continuation of such conditions cannot but add materially to the value of the Station and increase the esteem in which its work is held by the people of the State.

HORTICULTURAL DIVISION.

REPORT OF THE HORTICULTURAL DIVISION.

FRED W. CARD AND A. E. STENE.

THE BLOOMING PERIOD OF FRUITS.

In 1899 the department was asked to keep a record of the blooming period of fruits on the Station grounds. These records were being gathered from various parts of the United States by a student interested in the problem of self-sterility.

In 1900 notes were not gathered upon the blooming period, but were resumed in 1901 and have been continued since. The records are here inserted, since knowledge of the date of bloom of different varieties often proves useful in the matter of planting to provide for interpollination.

To secure the benefits of mixing different varieties together in planting it is important that they should bloom together. A case in point is in evidence on the college grounds. One plum tree labeled Wild Goose does not bloom until the blossoms have fallen from all other varieties in its vicinity. This tree has never borne a crop of fruit, and the inference is that it is self-sterile and does not receive pollen from other varieties.

The blooming period in Rhode Island lasts longer than farther west. General observations seem to indicate this, and notes were obtained on a few varieties from Nebraska for comparison. The length of time the trees were in bloom in each of the two states, for the season in which the comparison was made, was as follows:

PLUMS.

	Rhode Island.	*Nebraska.*
Ogon	10 days.	9 days.
Satsuma	12 "	5 "
Abundance	10 "	3 "
Rollingstone	5 "	9 '

CHERRIES.

Early Richmond	19 days	16 days.
Montmorency	21 "	10 "

BLOOMING PERIOD.

VARIETY.	FIRST.				FULL.				FALLEN.			
	1899.	1901.	1902.	1903.	1899.	1901.	1902.	1903.	1899.	1901.	1902.	1903.
APPLES.												
Acuba-leaved Reinette.	....	May 23	May 13	May 11	....	May 25	May 17	May 16	....	June 3	May 23	May 24
Alexander.	....	" 25	" 18	" 11	....	" 30	" 21	" 16	....	" 8	" 25	" 21
Arctic.	....	" 24	" 18	" 10	....	" 27	" 22	" 15	....	" 5	" 23	" 20
Baldwin.	....	" 24	" 14	" 11	....	" 28	" 21	" 16	....	" 5	" 26	" 22
Ben Davis.	May 15	" 23	" 13	" 16	May 22	" 27	" 20	" 19	May 29	" 8	" 26	" 23
Belle de Boskoop.	" 19	" 23	" 15	" 10	" 28	" 28	" 22	" 15	June 4	" 7	" 29	" 20
Bough, *Sweet*.	" 17	" 23	" 15	" 11	" 23	" 30	" 20	" 16	May 29	" 8	" 27	" 22
Bietigheimer	" 19	" 22	" 11	" 7	" 22	" 24	" 17	" 12	" 29	" 3	" 24	" 20
Brownett Russet.	" 15	" 22	" 11	" 11	" 23	" 24	" 18	" 16	" 28	" 5	" 23	" 22
Carlough.	....	....	" 19	" 13	....	....	" 22	" 18	....	....	" 24	" 21
Chicago.	....	May 22	" 8	" 13	....	May 25	" 17	" 18	....	" 3	" 23	" 22
Cooper Market.	May 16	" 24	" 15	" 13	May 24	" 30	" 19	" 18	May 29	" 5	" 26	" 22
Coral.	....	" 22	" 15	" 8	....	" 25	" 21	" 13	....	" 4	" 23	" 20
Cox.	May 13	" 23	" 15	" 9	May 24	" 30	" 22	" 16	May 30	" 10	" 27	" 21
Dartmouth.	" 12	....	" 10	" 7	" 18	....	" 17	" 13	" 25	....	" 23	" 18
Dominie.	" 13	May 21	" 8	" 7	" 20	May 24	" 17	" 12	" 27	June 2	" 27	" 19
Early Harvest.	" 15	" 21	" 11	" 8	" 22	" 25	" 20	" 15	" 29	" 4	" 27	" 21
Early Strawberry.	....	....	....	" 9	....	....	....	" 15	....	....	....	" 19
Fallawater.	May 15	May 24	May 13	" 9	May 25	May 30	May 22	" 15	May 30	June 7	May 29	" 20
Fanny.	....	" 24	....	" 9	....	" 27	....	" 13	....	" 2	....	" 18

BLOOMING PERIOD.

VARIETY.	First.				Full.				Fallen.			
	1899.	1901.	1902.	1903.	1899.	1901.	1902.	1903.	1899.	1901.	1902.	1903.
Apples.												
Fishkill	May 15	May 23	May 14	May 9	May 22	May 25	May 18	May 14	May 27	June 4	May 25	May 20
Golden Russet	....	" 23	" 10	" 9	....	" 27	" 16	" 15	....	" 3	" 23	" 20
Grimes *Golden*	May 16	" 23	" 12	" 11	May 22	" 27	" 18	" 15	May 27	" 5	" 24	" 21
Hubbardston	" 15	" 24	" 14	" 11	" 25	" 27	" 21	" 16	" 31	" 3	" 31	" 22
Hyslop	....	" 22	" 11	" 8	....	" 24	" 17	" 14	....	" 3	" 23	" 19
Keswick	May 13	" 22	" 8	" 9	May 23	" 26	" 17	" 14	May 29	" 5	" 23	" 19
Lady	" 12	....	" 9	" 8	" 15	....	" 16	" 13	" 23	....	" 23	" 16
Lady Sweet	....	May 23	" 18	" 9	....	....	" 23	" 15	....	....	" 26	" 21
Lord Suffield	May 16	" 23	" 11	" 8	May 23	May 28	" 19	" 14	May 27	June 4	" 24	" 20
Lyman Pumpkin Sweet	....	" 23	" 18	" 11	....	" 30	" 22	" 16	....	" 7	" 27	" 22
Mann	....	" 22	" 10	" 8	....	" 25	" 18	" 15	....	" 3	" 24	" 20
Marengo	....	" 23	" 10	" 9	....	" 24	" 14	" 13	....	May 31	" 21	" 18
Minnesota Winter	May 13	" 20	" 8	" 5	May 15	" 23	" 13	" 12	May 25	June 3	" 25	" 20
Missouri *Pippin*	" 13	" 23	" 13	" 9	" 24	" 27	" 21	" 13	" 29	" 3	" 26	" 19
Northern Spy	....	....	....	....	....	....	....	....	....	....	....	....
Northwestern *Greening*	....	May 28	....	May 13	....	....	....	May 16	....	....	....	May 21
Occident	....	" 27	....	" 15	....	....	....	" 19	....	....	....	" 25
Orange	May 15	" 23	....	" 6	May 19	May 25	....	" 11	May 27	June 3	....	" 18
Palmer *Greening*	" 15	" 23	May 12	" 9	" 24	" 28	May 20	" 13	" 30	" 8	May 26	" 18
Paul Imperial	....	" 21	" 8	" 7	....	" 23	" 16	" 14	....	" 1	" 22	" 19

BLOOMING PERIOD.

VARIETY.	FIRST.				FULL.				FALLEN.			
	1899.	1901.	1902.	1903.	1899.	1901.	1902.	1903.	1899.	1901.	1902.	1903.
APPLES.												
Peck *Pleasant*	May 15	May 24	May 17	May 13	May 24	May 31	May 22	May 18	May 27	June 4	May 26	May 22
Pewaukee	" 15	" 21	" 10	" 9	" 22	" 25	" 18	" 14	" 29	" 3	" 26	" 20
Pomme Grise	....	" 21	" 9	" 7	....	" 24	" 17	" 11	....	" 3	" 24	" 20
Primate	May 12	" 20	" 8	" 8	May 19	" 24	" 17	" 14	May 26	" 3	" 23	" 20
Pumpkin Sweet	....	" 23	" 16	" 9	....	" 25	" 20	" 14	....	" 1	" 25	" 21
Quaker Beauty	....	" 22	" 10	" 9	....	" 24	" 18	" 16	....	" 4	" 23	" 21
Rambo	May 20	" 27	" 14	" 15	May 28	....	" 19	" 19	June 3	....	" 26	" 23
Ralls *Genet*	" 20	June 1	" 20	" 18	" 28	June 4	" 26	" 18	" 2	June 9	June 4	" 22
Red Astrachan	" 13	May 21	" 11	" 8	" 19	May 23	" 16	" 14	May 25	" 1	May 22	" 18
Red Canada	" 19	" 23	" 14	" 9	" 22	" 30	" 21	" 16	June 2	" 7	" 27	" 22
Red June	May 15	....	" 13	" 13	May 26	....	May 19	" 18	June 3	....	May 25	" 21
Red Russet	....	....	" 14	" 10	....	....	" 20	" 16	....	....	" 26	" 22
Red Siberian	May 12	May 22	" 18	" 9	May 15	May 24	" 16	" 14	May 23	June 1	" 22	" 21
Rhode Island *Greening*	" 15	....	" 11	" 8	" 22	....	" 18	" 13	" 29	....	" 27	" 20
Roxbury *Russet*	" 16	May 23	" 11	" 7	" 28	May 26	" 18	" 12	June 2	June 8	" 27	" 20
Smith *Cider*	" 15	" 24	" 12	" 13	" 22	" 27	" 19	" 18	May 27	" 3	" 26	" 26
Sops of Wine	" 19	" 21	" 13	" 7	" 24	" 24	" 20	" 12	" 29	" 3	" 25	" 22
St. Lawrence	....	" 23	" 12	" 11	....	" 30	" 20	" 16	....	" 4	" 28	" 22
Stump	May 18	" 23	" 14	" 9	May 23	27	" 20	" 14	May 27	" 1	" 24	" 21
Summer Rose	" 19	" 23	" 14	" 11	" 26	June 2	" 22	" 16	June 1	" 8	" 28	" 21

BLOOMING PERIOD.

VARIETY.	First.				Full.				Fallen.			
	1899.	1901.	1902.	1903.	1899.	1901.	1902.	1903.	1899.	1901.	1902.	1903.
Apples.												
Swaar	May 15	May 22	May 13	....	May 19	May 24	May 18	....	May 25	June 3	May 24	....
Tolman *Sweet*	....	“ 24	....	....	....	“ 27	....	....	....	“ 5	....	....
Tetofski	....	May 25	May 14	May 9	....	....	May 19	May 12	....	....	May 25	May 21
Tompkins King	....	....	“ 12	“ 13	....	....	“ 18	“ 16	....	....	“ 24	“ 22
Transcendent	May 14	“ 21	“ 9	“ 9	May 19	May 24	“ 16	“ 15	May 27	May 30	“ 23	“ 20
Transparent Currant	....	“ 21	“ 9	“ 8	....	“ 24	“ 16	“ 16	....	June 6	“ 25	“ 22
Telfer Sweet	....	“ 22	“ 13	“ 9	....	“ 24	“ 19	“ 15	....	“ 3	“ 22	“ 20
Tuft Baldwin	....	....	“ 14	“ 13	....	....	“ 20	“ 16	....	....	“ 28	“ 21
Twenty Ounce	May 15	May 23	“ 11	“ 9	May 22	May 27	“ 18	“ 16	May 26	June 3	“ 24	“ 22
Vandevere	“ 16	“ 23	“ 13	“ 9	“ 23	“ 26	“ 18	“ 12	“ 29	“ 5	“ 26	“ 17
Wagener	“ 13	....	“ 11	“ 9	“ 20	....	“ 18	“ 15	“ 27	....	“ 25	“ 20
Walbridge	....	May 22	“ 14	“ 11	....	May 28	“ 21	“ 16	....	June 7	“ 26	“ 23
Washington	....	“ 22	“ 14	“ 15	....	“ 27	“ 21	“ 19	....	“ 5	“ 28	“ 25
Wealthy	....	“ 23	“ 14	....	....	“ 25	“ 20	....	....	“ 3	“ 29	....
Westfield *Seek-no-Further*	....	....	“ 16	May 9	....	....	“ 21	May 16	....	....	“ 26	May 20
White Pippin	May 15	May 24	“ 13	“ 8	May 22	May 30	“ 22	“ 14	May 27	June 6	“ 29	“ 20
Williams *Favorite*	“ 19	“ 24	“ 18	“ 10	“ 28	June 3	“ 28	“ 18	June 4	“ 10	June 3	“ 22
Winesap	“ 18	“ 23	“ 14	“ 10	“ 24	“ 1	“ 21	“ 16	May 29	“ 6	May 29	“ 20
Yellow Bellflower	“ 16	“ 23	“ 12	“ 9	“ 27	May 28	“ 20	“ 15	“ 27	“ 5	“ 25	“ 22

BLOOMING PERIOD.

VARIETY.	FIRST.				FULL.				FALLEN.			
	1899.	1901.	1902.	1903.	1899.	1901.	1902.	1903.	1899.	1901.	1902.	1903.
APPLES.												
Yellow Siberian	May 10	May 21	May 10	May 7	May 15	May 24	May 18	May 14	May 25	June 3	May 24	May 20
Yellow Transparent	" 15	" 23	" 13	" 10	" 24	" 27	" 20	" 15	" 29	" 3	" 28	" 20
York Imperial	" 17	" 24	" 17	" 13	" 27	June 1	" 22	" 18	" 31	" 8	" 29	" 22
CHERRIES.												
Eagle, *Black*	May 16	May 13	May 3	Apr. 27	May 8	May 16	May 9	Apr. 30	May 15	May 30	May 16	May 11
Eugenie, *Empress*	" 6	" 13	" 2	" 29	" 11	" 17	" 7	May 3	" 22	May 30	" 19	" 13
Florence	" 4	" 12	" 2	" 29	" 9	" 15	" 10	" 3	" 19	" 30	" 16	" 12
Hortense, *Reine*	" 7	" 14	" 6	" 29	" 12	" 14	" 13	" 7	" 22	" 30	" 22	" 13
Montmorency	" 8	" 16	" 6	May 3	" 16	" 22	" 13	" 9	" 29	" 30	" 22	" 16
Richmond, *Early*	" 8	" 14	" 6	" 4	" 15	" 22	" 15	" 10	" 27	June 1	" 24	" 18
Tartarian, *Black*	" 3	" 13	" 3	Apr. 27	" 9	" 16	" 8	Apr. 30	" 16	May 30	" 15	" 15
PEARS.												
Anjou	....	May 17	May 8	Apr. 30	....	May 21	May 10	May 6	....	May 30	May 20	May 15
Assumption	....	" 22	" 11	May 7	....	" 24	" 13	" 9	....	" 31	" 21	" 16
Bartlett	May 14	" 18	....	" 1	May 19	" 22	....	" 4	May 21	" 30	....	" 15
Brandywine	....	....	....	....	....	....	....	....	....	....	....	....
Boussock	....	....	....	....	....	....	....	....	....	....	....	....
Clairgeau	May 12	May 21	May 8	Apr. 30	May 13	May 23	May 11	May 6	May 17	May 25	May 17	May 14

BLOOMING PERIOD.

VARIETY.	First.				Full.				Fallen.			
	1899.	1901.	1902.	1903.	1899.	1901.	1902.	1903.	1899.	1901.	1902.	1903.
Pears.												
Clapp *Favorite*	....	May 21	May 10	May 5	....	May 23	May 15	May 9	....	June 1	May 22	May 16
Dearborn	....	" 17	" 6	Apr. 30	....	" 21	" 8	" 4	....	May 26	" 19	" 16
Danas Hovey	....	" 22	....	May 6	....	" 24	....	" 11	....	June 2	....	" 18
Doyenne	....	" 21	....	Apr. 30	....	" 22	....	" 5	....	May 30	....	" 13
Easter *Beurre*	....	" 16	....	" 30	....	" 21	....	" 5	....	" 25	....	" 13
Eastern Belle	May 13	" 20	....	May 4	May 15	" 23	....	" 11	May 19	June 1	....	" 16
Elizabeth, *Mannings*	" 8	" 16	May 8	Apr. 30	" 10	" 20	May 10	" 4	" 19	May 27	May 19	" 16
Fortunee	....	....	" 11	May 5	....	....	" 17	May 10	....	....	" 22	" 15
Frederick Clapp	....	May 17	....	" 4	....	May 22	....	" 10	....	June 1	....	" 19
Hardy	May 10	" 19	May 8	Apr. 30	May 12	" 23	May 10	" 5	May 20	May 30	May 19	" 16
Hoosic	....	" 20	....	May 3	....	" 22	....	" 7	....	" 30	....	" 15
Howell	May 10	....	....	....	May 13	....	....	....	May 22	....	....	....
Kieffer	" 7	May 16	May 4	Apr. 30	" 10	May 21	May 8	May 6	" 16	May 25	May 19	May 15
Lawrence	" 9	" 17	" 6	" 30	" 13	" 21	" 8	" 5	" 20	" 28	" 17	" 14
Louis *Bonne*	" 10	" 17	" 8	May 4	" 13	" 21	" 12	" 10	" 22	" 28	" 20	" 16
Margaret	....	" 17	" 8	Apr. 30	....	" 21	" 11	" 6	....	" 27	" 19	" 14
Maurice Desportes	....	....	....	May 3	....	....	....	" 7	....	....	....	" 16
Monceau	....	May 21	May 9	" 2	....	May 23	May 12	" 8	....	May 27	May 21	" 15
Nickerson	....	....	....	" 5	....	....	....	" 14	....	....	....	" 18
Pitmaston Duchess	May 10	May 19	May 8	Apr. 30	May 13	May 22	May 10	" 6	May 24	May 30	May 20	" 18

BLOOMING PERIOD.

VARIETY.	First.				Full.				Fallen.			
	1899.	1901.	1902.	1903.	1899.	1901.	1902.	1903.	1899.	1901.	1902.	1903.
Pears.												
Pound	....	May 17	....	....	....	May 21	....	....	....	May 30	....	....
President Mas	May 12	" 17	....	Apr. 29	May 15	" 21	....	May 5	May 22	" 28	....	May 19
Seckel	" 13	" 20	May 9	May 1	" 15	" 22	May 11	" 9	" 22	June 1	May 19	" 16
Sheldon	....	" 19	....	" 5	....	" 22	....	" 9	....	May 30	....	" 18
Superfine	May 13	" 20	May 8	" 9	May 15	" 22	May 10	" 12	May 19	" 30	May 19	" 18
Souvenir d'Esperen	" 9	" 16	" 6	Apr. 30	" 13	" 21	" 8	" 5	" 22	" 31	" 21	" 15
Therese Appert	" 11	....	" 8	" 30	" 15	....	" 13	" 7	" 7	....	" 20	" 16
Urbaniste	....	May 16	....	" 30	....	" 21	....	" 5	....	May 27	....	" 16
Winter Nelis	May 13	" 23	" 11	May 6	May 17	" 24	May 15	" 9	May 27	June 3	May 22	" 20
Plums.												
Abundance	May 3	May 12	May 29	Apr. 25	May 9	May 15	May 6	Apr. 29	May 13	May 20	May 13	May 5
Arctic	" 7	" 15	" 5	" 30	" 10	" 17	" 8	May 5	" 19	" 22	" 16	" 11
Berckman	" 3	" 11	Apr. 28	" 26	" 10	" 14	" 4	Apr. 29	" 16	" 20	" 9	" 1
Burbank	" 2	" 9	May 1	" 20	" 8	" 14	" 8	" 27	" 12	" 22	" 10	" 5
Choptank	....	" 21	" 12	May 7	....	" 24	" 18	May 11	....	June 2	" 24	" 17
Czar	....	....	" 6	Apr. 30	....	....	" 8	" 5	....	....	" 10	" 14
Englebert *Prince*	May 8	" 15	" 5	" 27	May 9	May 17	" 8	Apr. 30	May 12	May 23	" 16	" 10
German *Prune*	....	" 20	" 9	May 5	....	" 23	" 14	May 10	....	" 30	" 20	" 16
Giant Prune	....	" 17	" 6	" 4	....	" 19	" 8	" 8	....	" 30	" 18	" 16
Grand Duke	May 10	....	" 6	" 1	May 12	....	" 8	" 6	May 13	....	" 16	" 11

BLOOMING PERIOD.

VARIETY.	First.				Full.				Fallen.			
	1899.	1901.	1902.	1903.	1899.	1901.	1902.	1903.	1899.	1901.	1902.	1903.
Plums.												
Gueii	May 8	May 16	May 3	Apr. 28	May 9	....	May 6	May 3	May 15	May 20	May 13	May 11
Hudson River Purple	....	" 16	" 6	" 19	....	May 20	" 8	" 4	....	" 23	" 16	" 11
Hulings *Superb*	....	....	" 2	" 29	....	....	" 5	" 4	....	....	" 12	" 11
Ickworth	....	May 17	" 8	May 2	....	May 22	" 11	" 6	....	May 30	" 22	" 16
Jefferson	....	" 20	" 8	" 1	....	" 22	" 11	" 6	....	" 30	" 20	" 14
Lafayette	May 9	" 16	" 7	" 2	May 11	" 21	" 10	" 6	May 23	" 30	" 23	" 18
Ogon	" 3	" 12	" 30	Apr. 29	" 8	May 14	" 3	Apr. 30	" 13	" 20	" 12	" 3
Pond	....	" 17	" 9	May 5	....	" 22	" 11	May 11	....	" 26	" 15	" 18
Prunus Pissardi	May 3	" 11	" 2	" 3	May 9	" 14	" 5	" 5	May 14	" 22	" 12	" 11
Prunus Simoni	" 2	" 8	" 29	" 1	" 6	" 13	" 2	" 4	" 12	" 20	" 8	" 9
Quackenboss	" 7	" 14	" 3	Apr. 28	" 9	" 16	" 8	Apr. 30	" 15	" 22	" 16	" 9
Rollingstone	" 10	" 16	" 6	" 30	" 12	" 20	" 9	May 5	" 13	" 25	" 16	" 15
Royal	....	" 15	" 6	May 4	....	" 17	" 8	" 7	....	" 23	" 17	" 12
Satsuma	May 3	" 9	" 30	Apr. 26	May 9	" 14	" 5	Apr. 30	May 15	" 23	" 10	" 6
Sophia	....	" 22	" 13	May 6	....	" 24	" 19	May 10	....	June 2	" 24	" 11
Spaulding	....	" 15	" 6	Apr. 29	....	" 17	" 8	" 1	....	May 22	" 15	" 7
Transparent	....	" 15	" 6	May 4	....	" 17	" 10	" 6	....	" 22	" 15	" 12
Yellow Egg	....	" 15	" 6	Apr. 29	....	" 17	" 8	" 5	....	" 22	" 16	" 12
Washington	....	" 15	" 6	" 30	....	" 17	" 8	" 5	....	" 22	" 15	" 13
Wickson	May 4	" 10	Apr. 28	" 27	May 10	" 14	" 3	" 1	May 15	" 22	" 12	" 5
Wild Goose	" 15	" 20	May 13	May 7	" 22	" 25	" 20	" 11	" 27	June 3	" 25	" 18

CLOVER.

Some preliminary tests with clover under different methods of treatment may have a passing interest, and are reported here. The primary object of the tests was to determine whether seed gathered from plants growing in old pastures where the soil is known to be acid would produce plants better adapted to thrive upon acid soil than that from other sources. The tests were made in six-inch pots, the seed being sown October 29, 1902. Four types of soil were used:

1. Exhausted soil from the Experiment Station plain, very acid.
2. Leaf-mold, very acid.
3. Soil from pasture land, acid.
4. Garden soil, slightly acid, mixed with well rotted stable manure, two parts soil to one part manure.

Five pots each of the above soils were sown, thus making twenty pots in the series. The kinds of seed were as follows: (*See Fig.* 1.)

1. Seed gathered from acid pasture land.
2. Seed gathered from acid meadow land.
3. Mammoth clover seed from same source as that of the Medium Red.
4. Medium Red clover seed received from a dealer in spring of 1902.
5. Medium Red clover seed as above, but with the addition of lime to each pot.

Another series of eight pots was sown, using the exhausted acid soil from the Experiment Station plain as a basis, this series being made up as follows: (*See Fig.* 2.)

1. Exhausted soil.
2. Exhausted soil with fertilizer.
3. Exhausted soil with leaf-mold.
4. Exhausted soil with leaf-mold and fertilizer.

5, 6, 7, and 8 are duplicates of the above but with the addition of lime.

Where fertilizer was used the amount per pot was as follows in each case:

.2 (two-tenths) gram nitrate of soda, .2 (two-tenths) gram muriate of potash, 1 gram acid phosphate.

The amount of air-slaked lime used per pot in the lime series was 1.5 gram. These amounts were designed to approximate 400 pounds nitrate of soda, 400 pounds muriate of potash, 2,000 pounds acid phosphate and 3,000 pounds of lime per acre. The seed used in this series was that gathered from acid meadow land as above. Leaf-mold, where used, was added in the proportion of one part mold to two parts soil. The plants of Mammoth and Medium Red began to appear above the ground in five or six days. The seed gathered from the fields germinated much more slowly, indicating perhaps that age or drying hastens germination. Lime hastened the start in pasture soil but seemed to hinder it in garden soil. Removing the hulls from seeds gathered from the fields or leaving them on caused very little difference.

An improvement was soon seen in the mechanical condition of the exhausted soil to which lime had been applied. This soil had become deficient in freshly decaying organic matter, and inclined to puddle under ordinary treatment. The lime seemed to render it more friable. The influence of acidity and fertility soon began to be felt. In leaf-mold, the limed plants were decidedly better than the unlimed; in pasture soil they were perhaps a little better; while in garden soil those without lime seemed to lead. The plants in garden soil were noticeably lighter in color than those in acid soil. In leaf-mold, particularly, which is very acid, they had a blue or dark purple cast. By the end of December all plants from seed gathered in the vicinity were very poor except those in garden soil. The ones in leaf-mold were nearly dead. The plants of Mammoth Red were poor in the exhausted soil, but much better in pasture soil. Four or five in leaf-mold were also good, the rest all very poor. In garden soil they were good. The plants of Medium Red, unlimed, were poor in all except the garden soil. In this soil the Medium Red, unlimed, proved better than any of the others.

Lime had begun to prove helpful to the Medium Red in leaf-mold and to some extent in the pasture soil, but not in the garden soil. At that time the poorest plants in either series were those growing in leaf-mold, except three or four plants of Mammoth Red. Lime seemed to be more or less advantageous to all but the Medium Red in garden soil. Seed gathered from the fields produced plants resembling Mammoth Red in character more than Medium Red. Some indication began to appear that Mammoth Red may stand acidity better than Medium. By the middle of January many of the plants in leaf-mold were dead. Four plants of the Mammoth Red began to stand out as a marked exception, the rest being small and poor. Those with lime were a little better, but small and dying. Plants in the exhausted soil were all very poor, Medium Red appearing rather better than Mammoth, and the unlimed appearing as good as the limed. In garden soil all the plants were good, the Medium being larger than the Mammoth and the unlimed rather better than the limed. In the exhausted soil test the plants were all very poor but those in the pots with fertilizer, with lime and fertilizer, and lime, leaf-mold and fertilizer were somewhat better than the others. The plants were photographed at the date of these observations.

By the end of January the Mammoth Red had begun to lead in pasture soil, followed by Medium Red limed. At the middle of February the four plants of Mammoth Red which had been noticeable in the leaf-mold were far ahead of any others in that soil. All others were dead or making no growth, except a few of the Medium Red in the limed leaf-mold pot, which showed a few plants. The Mammoth Red was much ahead in pasture soil. In the exhausted soil the Medium Red, unlimed, was best. During the latter part of the winter the plants met with many vicissitudes. Owing to the failure of the coal supply, it became necessary to move them to a small house connected with the poultry plant. The conditions there were poor, and on at least one or two occasions the ground in the house was crusted with frost in the morning. Toward the end of February they were moved back into the old greenhouse, but no heat was applied. A very cold spell came on, during which they were covered with burlap, but rats worked under the burlap and ate off the tops of many of them. The ground was frozen at times. By the middle of April they had overcome the effects of this treatment, and the plants in some of the pots were very vigorous and thrifty. Plants produced from seed gathered in the neighboring fields were all very poor except in the garden soil. The Medium Red was doing almost as well in the pasture soil as in the garden soil. The four plants of Mammoth Red in leaf-mold which had stood out so prominently during the test were making an excellent growth, but in the exhausted soil from the Experiment Station plain Mammoth Red does not do so well as Medium. In nearly all cases except that of the garden soil the Medium Red plants in limed pots were doing better than in the unlimed, but the difference was not sufficient to afford a good growth in the acid soils even when limed. In the garden soil the plants were not quite so strong nor so dark in color in the limed pot as in the unlimed one. None of the plants in the exhausted plain soil made a good growth. It seemed from this test that something more is needed than fertilizer, lime, and mechanical condition, or at least such a mechanical condition as that produced by an admixture of leaf-mold.

By midsummer the strongest lot of all was the Mammoth Red in pasture soil, this being even better than any of those in garden soil. In the exhausted soil the limed pots had begun to show an advantage over the unlimed. The plants of Mammoth Red which had thrived throughout in the acid leaf-mold still continued to make a fair growth. In the exhausted soil test the pot which had received fertilizer only made the best showing. The Mammoth Red plants from pasture soil and from leaf-mold were set in the open ground, also those produced from seed gathered in acid meadow land and sown in leaf-mold in which a few plants were still growing and apparently fairly healthy, although small.. The other plants were discarded. Examinations of the roots showed comparatively few nodules except here and there. As a rule more were found upon those plants growing in pasture soil than elsewhere.

This is only a preliminary test, and cannot be considered to carry

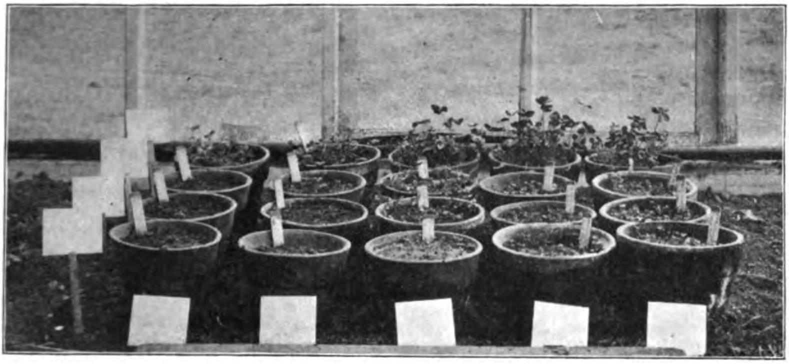

FIG. 1.

Soil Tests with Clover.

Row 1. From front to back. Plain soil.
" 2. " " " Leaf-mold.
" 3. " " " Pasture soil.
" 4. " " " Garden soil.
Row 1. From left to right. Seed from acid pasture land.
" 2. " " " Seed from acid meadow land.
" 3. " " " Mammoth Red seed.
" 4. " " " Medium Red seed.
" 5. " " " Medium Red, limed.

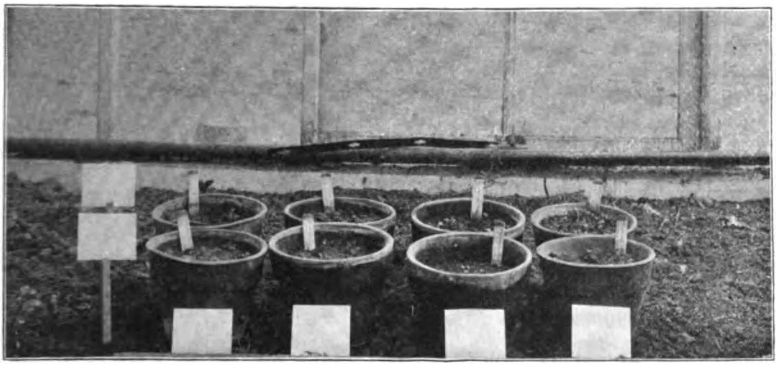

FIG. 2.

Soil Tests with Clover.

Front row, unlimed. Back row, limed.

Row 1. From left to right. Plain soil.
" 2. " " " Plain soil with leaf-mold.
" 3. " " " Plain soil with fertilizers.
" 4. " " " Plain soil with fertilizers and leaf-mold.

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much weight. It does seem to indicate, however, that there is a difference in the ability of plants to resist acidity, and that in this particular case the Mammoth clover was able to thrive better in an acid soil than the Medium. In the spring of 1903 seed of Medium and Mammoth varieties was obtained from a number of seedsmen and planted side by side in open ground, in hills, to afford opportunity to observe the individuality of plants, in order if possible to seize upon any desirable variations or types for perpetuation. The clover plant is one of our most important forage plants, yet little has been done to improve it. Doubtless it varies in many of its characteristics, including protein content and other points which may give it value. It is hoped that as time goes on something may be learned regarding these points.

COLOR OF FLOWERS.

The experiment to test the effect of nitrogen, of potash, and of sugar upon the color of flowers was continued in 1902. The seeds chosen for the purpose were as follows: Phlox, balsam, branching aster, comet aster, carmine, peach blossom, ten-weeks stock. The seeds were ordered from J. M. Thorburn & Co., and the colors chosen were chiefly light red in order to afford opportunity to test the effect upon the intensity of red. The plots chosen were upon nearly level ground, free from shade or other varying influences. The seeds did not germinate well, but afforded enough plants for comparison in most cases. Early in July, when the plants were from one-half an inch to five inches tall, fertilizers were applied. It was spread as evenly as possible over the entire plot, extending six inches beyond either end of the row and 1½ feet on the sides, making the plots 9x18 feet, containing 162 square feet. The materials were applied at the rate of 1,000 pounds per acre. The ground between the rows was then gone over. with a wheel hoe, and the fertilizer worked into the rows with onion hoes. This was done the day following a good rain. This heavy application of nitrate of soda and of muriate of potash injured many of the plants, especially the phlox and balsam. No injury followed the application of sugar. An additional application of sugar was made to the phlox and balsam plants at the end of July. Observations made from time to time, throughout the season, showed no influence whatever upon color as a result of these different applications. Since these results agree with those of the previous year, it seems fair to assume that under ordinary field conditions any reasonable application of nitrate of soda, of muriate of potash, or of sugar will not materially intensify or reduce red color in flowers.

CORN SELECTION.

Experiments in selection of sweet corn to increase the number of ears per stalk, begun in 1898, were continued as heretofore in the year 1902. The seed this year was in poor condition, having molded from being placed in tight seed drawers when apparently dry enough to store. All the suitable seed which could be obtained was planted. The selection, it should be explained, has gone on in two ways. In one line, seed has been chosen from the lower ear of stalks bearing the largest number of ears; in the other case from the upper ear of stalks bearing the largest number of ears. The rows were three feet apart, and the land chosen was sod ground. The two plots were several rods apart, to prevent intermixing of pollen. The season was unusually wet and cold, so that corn was smaller and more backward than usual, but this made a fair growth with no injury from accidents. A detailed account of the stalks found at harvesting time appears below: (*See Fig.* 3.)

Selection From Lower Ear.

Total number of plants	762	
Plants with no ears	54	(7.1 per cent.)
Plants with one ear	408	(53.5 per cent.)
Plants with two ears	267	(35.0 per cent.)
Plants with three ears	31	(4.1 per cent.)
Plants with four ears	2	(0.3 per cent.)

Selection From Upper Ears. (*See Fig.* 4.)

Total number of plants	467	
Plants with no ears	31	(6.7 per cent.)
Plants with one ear	213	(45.6 per cent.)
Plants with two ears	141	(30.2 per cent.)
Plants with three ears	58	(12.4 per cent.)
Plants with four ears	20	(4.2 per cent.)
Plants with five ears	4	(0.9 per cent.)

It was noticed at harvesting time that in the plot grown from upper ears there were frequently from two to four stalks more in the hill than in the plot grown from lower ears. This was probably due to the greater vitality of the seed taken from upper ears, which are always better developed than lower ears. This appeared to influence the number of ears per stalk, as it was found usually that where only one or two stalks were growing in a hill they contained more ears than when the stalks were crowded. This influence has been guarded against in 1903 by dropping the seed singly a foot apart in the rows. The variation in thickness evidently worked to the disadvantage of seed chosen from upper ears, at least during the season of 1902. The results, however, bear out those previously secured in showing that more progress can be made by choosing seed from the upper ear than by choosing from the lower one, which doubtless means simply that we should choose well developed and thoroughly ripened seed from the best stalks, regardless of the point upon the stalk from which the seed is taken.

To indicate the progress made it may be stated that in 1900, the first year in which a detailed account of the stalks was made, there were no stalks in either line which bore more than two ears. (See Annual Report for 1902, page 245.) At the present time sufficient progress has been made so that in 1903 all the seed used in the upper ear selection was taken from stalks which bore five ears in 1902. It is further noticeable that the young plants produced from this seed are much more vigorous and show much better color at the present writing than those secured from seed taken from lower ears. Since the comparative advantage of upper and lower ears seems to be fairly well tested, and the supposition that to increase the number of ears one should choose always from the lower ear, because that is the last one developed, is shown to be erroneous, hereafter this line of work will be discarded and in the future, selection will go on from upper ears, or at least from well developed ears, only.

GASOLENE AS A REMEDY AGAINST ENEMIES OF THE SQUASH, CUCUMBER, AND PUMPKIN.

Gasolene has been suggested as a remedy against the squash borer and the larvæ of the striped beetle, which work in the roots of cucurbits. To test the effect in a practical way, gasolene was applied to cucumbers, squash, and pumpkin. Where growing in rows, holes were made in the ground about seven inches deep and gasolene poured in, using from two to four teaspoonfuls to each hole, the hole then being covered with soil. In the hills, holes were made in the center and a little larger amount of gasolene used. The first application was made June 30. The plants at that time were badly eaten by the striped beetle. The application was repeated July 7, July 15, July 22, July 29, and August 5. Observations at different times by different people failed to reveal any practical difference in the injury to treated or untreated plants.

The results do not justify the drawing of conclusions, except that in this case, gasolene proved wholly ineffective against these insects.

HUCKLEBERRIES.

The term "huckleberry" is one which means different things in different places. As used in New England it is limited to the black huckleberry (*Gaylussacia resinosa*); as used in other parts of the country it is a general term, made to include different forms of both *Vaccinium* and *Gaylussacia*. Experiments here described have to do with the high or swamp huckleberry, known everywhere in New

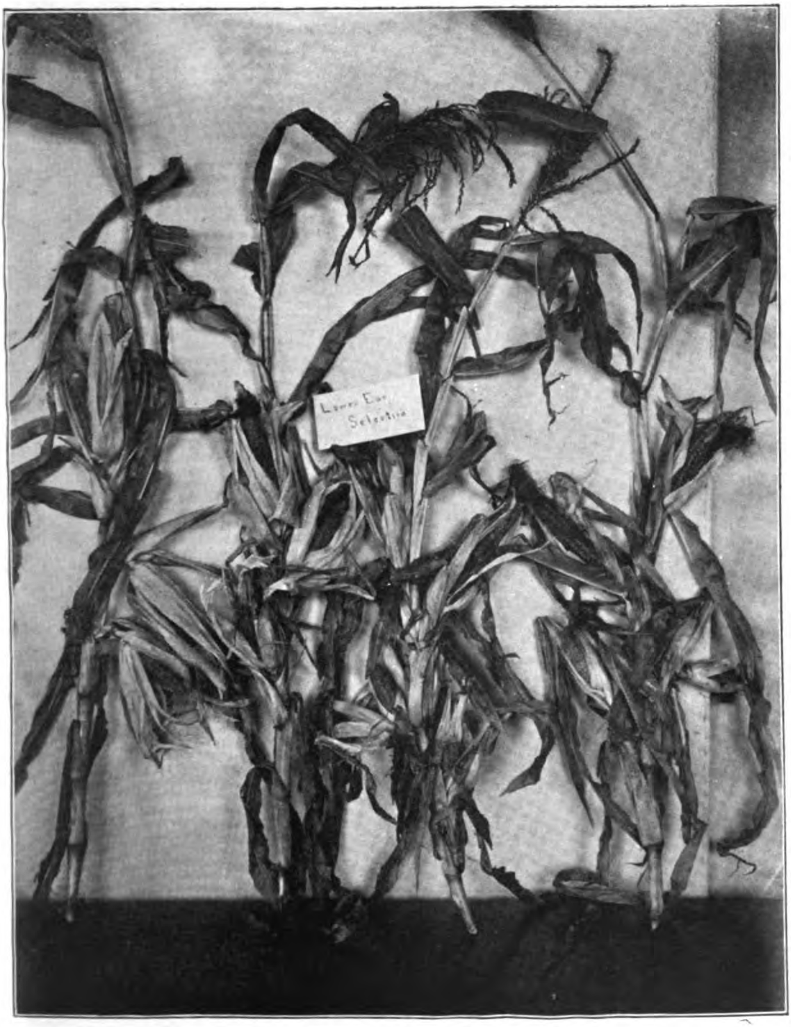

Fig. 3.

Corn Selections from Lower Ears.

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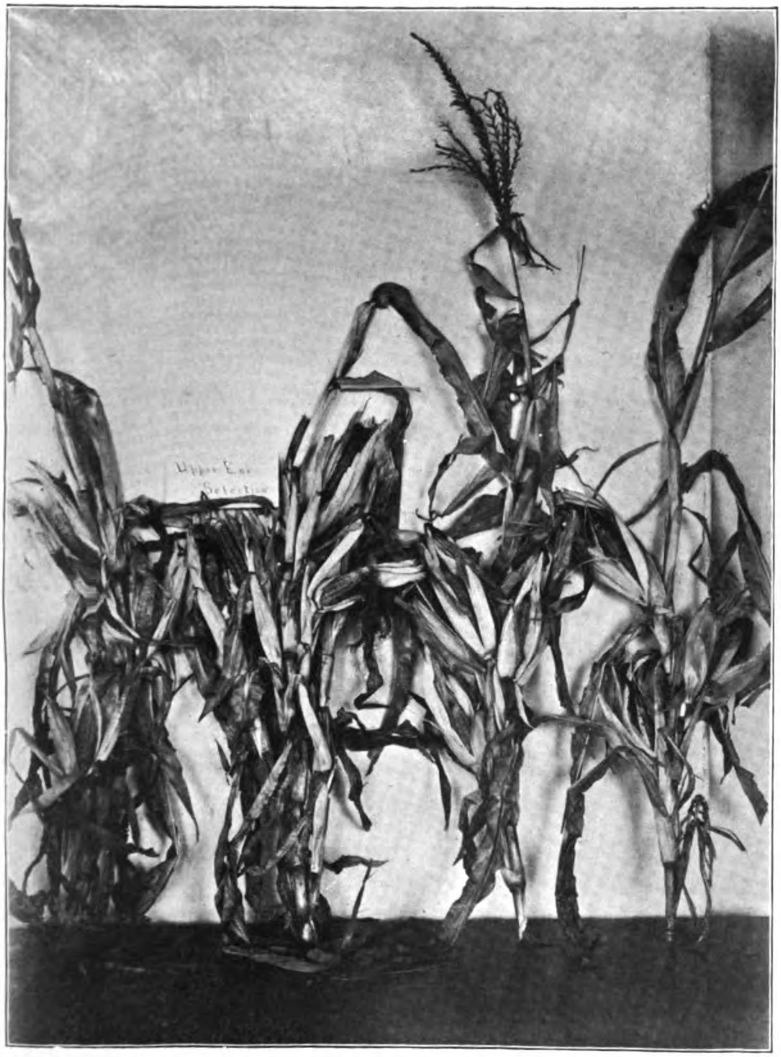

FIG. 4.
Corn Selections from Upper Ears.

England as "blueberry." There are two species which pass under this name, the more important being *Vaccinium corymbosum*, which bears large blue fruit and large whitish flowers. Another species, formerly included with this, is *Vaccinium atrococcum*. This bears smaller flowers and smaller fruit, which is black, and ripens earlier than that of *Vaccinium corymbosum*. The typical blueberry, *Vaccinium corymbosum*, is the most promising form for cultivation. Attempts have been made from time to time to grow it in gardens with varying success, much evidently depending upon the soil and the location. If it can be made to thrive over any large extent of territory it is one of our most desirable fruits. There are still unsolved questions regarding its needs in the matter of soil and care, but one of the chief hindrances of its spread in cultivation has been the difficulty of propagation. Seeds germinate readily, and with proper care it is easy to grow plants in this way, but it takes a long time. They make a slow growth, and one must needs have much patience in waiting for them to reach fruiting age. Furthermore, there is then no certainty that the most desirable forms can be perpetuated. Various attempts have been made to propagate this plant from cuttings.

Root-cuttings were placed in the greenhouse December 12, 1898. By the end of February they were beginning to show some growth. Stem-cuttings put in at the same time were showing buds. On March 18, 1899, both root and stem-cuttings dug directly from the field were placed in a propagating place having a slate bottom and several inches of moss as the material in which to start them. Panes of glass covered the top. A few of these root-cuttings were observed to be starting April 21st. At that date the root-cuttings put in sand December 12 were potted off, but none of them seemed to have thrown out any new roots and some had made no shoots. A number of the stem-cuttings were examined, but none had made roots. By the middle of May many stem-cuttings had made shoots and a few showed active callousing, but not a root had been formed. Many of the shoots had died. Early in May root-cuttings from plants taken directly from the fields were planted in the garden. July 21 the root-cuttings started in December and potted off in April were planted out in the open ground. Many of them had died, and no roots were to be seen on the outside of the ball of earth in any case. Many of the root-cuttings put in the propagating case in March had at that time made excellent growth. A minute root was observed emerging from one, which was the first root seen. Many of the stem-cuttings threw out good shoots, but no roots were to be seen. Part of the root-cuttings were potted off July 22. Many of them were well rooted, but others showed no roots whatever. Those with strong shoots were potted, but those showing little growth were returned to the moss. A few having fair shoots were placed outside in the open ground as a test. One of the stem-cuttings placed in the moss at the same time with the root-cuttings had developed a few roots. A few of the older stem cuttings placed in sand in December also had good roots. These were the first roots to be observed on stem-cuttings. Some of the root-cuttings placed in the open ground early in May were dug up and examined. Nearly all were sending up shoots, although only two or three in the row appeared above ground. The outcome of this work was that most of the plants when placed in the open ground lingered along for a time and disappeared.

In the fall of 1899 additional stem and root-cuttings were secured, part being placed in the greenhouse at once, others being buried outside, and still others placed in a cellar. Of those placed inside some were potted off in the middle of March, 1900. Those placed in sand were much slower to start than those placed in moss. Toward the end of March stem-cuttings and root-cuttings from outside and from the cellar were placed in the greenhouse. No indication of callousing could be observed upon either, whether buried in the open or left in the cellar during the winter. Stem-cuttings placed directly in the cutting-bed in the fall had done nothing.

April 21 root-cuttings buried in sand outside during winter others kept in the cellar, and still others taken directly from plants growing outside were planted in the open ground. The season was very dry, and these did but little. Only a few had appeared above ground at the end of July. Plants grown from seed sown in 1899 met with many hardships during the winter, but a number of them survived and were potted off in July, being at that time from two to four inches high, or little, if any, larger than root-cuttings started in the spring of 1900.

In 1901 root-cuttings were made from plants taken directly from the field May 18. This was probably somewhat later than would be desirable, since the plants were already in bloom. Pieces were cut about three inches long and planted in a moist garden in the village. They were placed in a trench and covered about three inches deep, three methods of planting being used:

1. Sphagnum moss was scattered in the bottom of the trench and over the cuttings before covering them with soil.

2. Soil taken from about the roots of the wild parent plants was scattered in the trench, the cuttings dropped, then covered with this soil in the same manner as the others were covered with moss, except that there was enough of this soil to nearly fill the trench.

3. The remainder were simply placed in the trench and covered with garden soil.

Thirty-five pieces were planted in each way. Toward the end of July a few shoots appeared from these root-cuttings. Notes made in August show that very few plants had been produced from the cuttings planted by either method. The larger number were from those covered with soil taken from where the plants grew, but even there the number was too small to render the method satisfactory. Most of these failed to survive the winter.

In 1902, in the latter part of March, cions were taken from selected plants, and roots were dug elsewhere. These cions were root-grafted April 3, and stored until planting time. Fifty-four root-grafts were made. These were put out in the garden April 24. They received no special attention, and practically all died before the summer was over. Thus far attempts at propagation were certainly not very encouraging.

A few attempts were made to cross the blue huckleberry and the blueberry, *Gaylussacia resinosa* and *Vaccinium corymbosum*. The black huckleberry spreads much more rapidly from its roots, and it was therefore presumed that it would be more easy to propagate it from root-cuttings. In a cross between the two it might be possible to obtain a plant having the good qualities of the blueberry, but more easily propagated. A few attempts made in 1902 and 1903 all failed. Evidently the species do not easily cross, and since there is no certainty of combining the qualities desired even when a cross is secured, this line of procedure seems to offer comparatively little promise in the matter of propagation.

In 1903 still other attempts were made, with a slight variation in the programme. Roots of *Vaccinium corymbosum* were dug March 11. Stem-cuttings from bushes known to produce fine fruit were taken at the same date. Cutting-beds were prepared on a slate bottom under the greenhouse bench in two ways. In one case sand was used with which was mixed soil taken from about the roots of those plants which were taken up. In the other case similar soil was mixed with sphagnum moss, the moss being some purchased from a distance in bailed form. Stem-cuttings were planted immediately. The following day root-grafts and root-cuttings were made and planted, the roots and stems having been covered carefully with moss to prevent them from drying. A little later a few root-grafts of *Vaccinium corymbosum* on roots of *Gaylussacia resinosa*, also root-cuttings of *Gaylussacia resinosa* were added. The planting represented the following numbers:

Sand and Soil.—43 stem-cuttings, 58 root-cuttings, 10 root-grafts, 3 crowns, 5 root-grafts of *Vaccinium* on *Gaylussacia*, 10 *Gaylussacia* root-cuttings.

Moss and Soil.—45 stem-cuttings, 66 root-cuttings, 10 root-grafts, 5 root-grafts of *Vaccinium* on *Gaylussacia*, 10 *Gaylussacia* root-cuttings.

By the end of April most of the stem-cuttings had thrown out strong buds or were starting well. The root-grafts did not seem

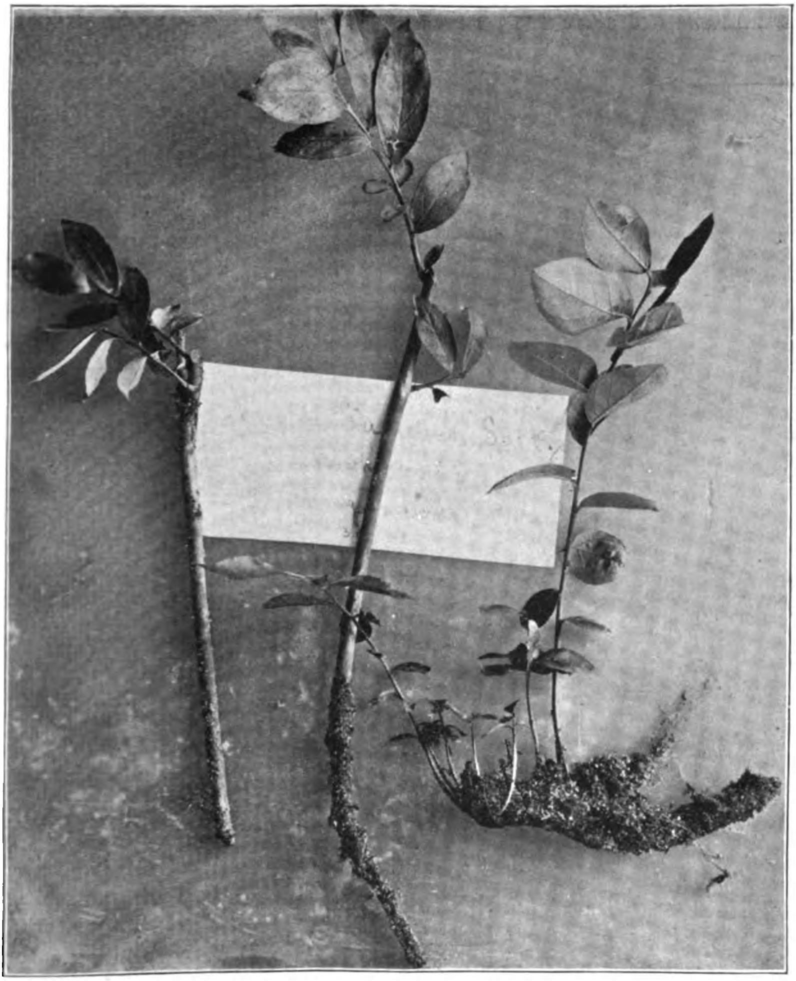

FIG. 5.

Blueberry Stem-cutting, Root-graft and Root-cutting—taken from Sand and Soil.

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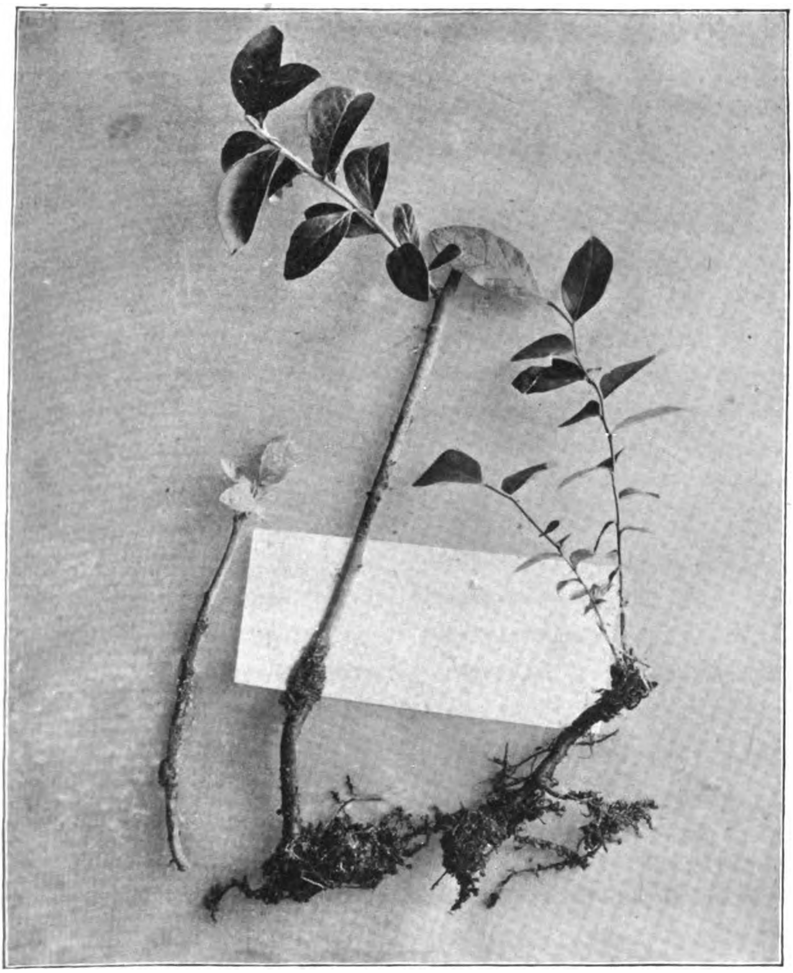

Fig. 6.

Blueberry Stem-cutting, Root-graft and Root-cutting—taken from Moss and Soil.

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quite so far advanced. Those in moss and soil were somewhat in advance of those in sand and soil. These beds were simply watered and left alone. By midsummer the condition was about as follows:

Of the 43 stem-cuttings in sand and soil, 19 still showed green shoots. Upon those examined, no roots were found. Of the 10 root-grafts in sand, 9 were growing and looked well. The root-cuttings were making a good showing; apparently a large precentage were growing, but they were planted so thickly that they could not well be counted. The crowns were growing well. Of the 5 *Vaccinium* grafts on *Gaylussacia* four were alive, one of which was growing well. Of the 10 *Gaylussacia* root-cuttings, 3 shoots were above ground. (*See Fig.* 5.)

Upon the 66 stem-cuttings in moss and soil there were 18 living shoots. A few roots were observed on one or two of these. Of the ten root-grafts 8 were growing and one other had been broken off but was throwing up shoots from the root. The root-cuttings hardly did so well in this case as in the sand. The root-grafts on *Gaylussacia* were not promising. The *Gaylussacia* root-cuttings were good.

All seemed to make roots much more freely in the moss and soil than in the sand and soil. It has been noticeable throughout the work that the plants make shoots much more readily than they make roots. Whatever encourages root-growth, therefore, is to be sought. Of the root-cuttings which were examined growing in the soil and sand, some had made an excellent growth of roots, though the roots formed are very fine and slender and would be easily destroyed unless care be taken in transplanting.

Here at last seems to be a promising outlook for the propagation of the blueberry. A moderate bottom heat, with moss in which is mingled soil taken from about the plants, seems to promise good results. Root-grafts under these conditions are showing a high percentage of living plants. It is easy to get miscellaneous roots anywhere in New England, and if root-grafts can be made, using cions from plants known to bear fine fruit, there is no reason why we should not propagate improved forms of this plant. The root-growth made, both from these root-grafts and the root-cuttings, indicates strongly that, with proper care from this time on, there should be no reason why these should not survive and make good plants. Growth, to be sure, is slow, and plants can never be sold at a cheap price, but there seems to be no reason why they cannot be furnished at a fair price. The behavior of the plants which we now have growing in cultivated land indicates that while they may be slow in gaining a foothold, as time goes on their growth improves. There seems to be no reason why they should not make excellent plants and give good results in garden culture.

ILEX.

Two species of *Ilex* common in New England pastures, are well worthy of planting for ornament, and, indeed, are so used to some extent.

Ilex verticillata, the winter berry, is a striking shrub in early winter, owing to the bright red color of its berries. *Ilex glabra*, the ink-berry, is not so conspicuous for its fruit, that being black and less abundant than that of the other species, but its foliage is evergreen; consequently, it is a very pretty shrub. If, by chance, the two grow together in one clump, we have a delightful combination, the red berries of one being supported by the evergreen foliage of the other. If, by crossing the two, it were possible to secure the evergreen foliage and the bright red berries upon the same plant, we should have a most delightful winter shrub. A few attempts at crossing have been made, but thus far without success.

The plants do not bear perfect flowers. In the winter berry the staminate blossoms are borne on one plant and the pistillate on another. In the ink-berry both may appear upon the same plant, but in either case the pistillate flowers are much fewer in number than the staminate and are sooner past blooming.

In 1902 buds of both series were covered July 2nd, without being emasculated. July 7th pollen from the opposite species was applied to these flowers. The attempted crosses included 12 clusters of

Ilex verticillata crossed by *Ilex glabra*, and 11 of *Ilex glabra* crossed by *Ilex verticillata*. The work was done on the afternoon of a bright sunny day. The pistils were sticky and apparently in fine working condition. There was also an abundance of pollen which adhered to the pistils well, so that failure could not be due to a lack of pollen. There were several blossoms on each twig treated. Later, it was found that some one had broken off every cluster of *Ilex verticillata* crossed by *Ilex glabra*. Those of the opposite cross remained, but all failed to set fruit.

A few further attempts have been made in 1903, but it is yet impossible to say with what results.

INJURY TO PEACH FOLIAGE FROM SPRAYING WITH BORDEAUX MIXTURE AND PARIS GREEN.

The work of the season has afforded some good illustrations of the damage done to peach foliage by spraying. In one case a peach tree coming in line with other trees was sprayed with Bordeaux mixture of ordinary strength, through an oversight of the workmen. The tree soon began to lose its leaves and in a short time was nearly defoliated. It soon put out new leaves, however, and by midsummer was in an apparently healthy condition. One cannot afford to risk such a check to the growth of a tree, unless demanded by special exigencies.

The other illustration of injury came about through spraying tests made in cooperation with the United States department of agriculture. For this work, samples of Paris green were furnished, containing free arsenious oxid varying from 2.84 per cent. to 8 per cent. Peach trees were sprayed with these different samples, used at the rate of 1 pound to 250 gallons of water, and other trees were sprayed at the same time with the same samples and the addition of twice as much lime as the amount of Paris green used.

The spraying was done at the end of May, during a period of continuous dry weather. Three days afterward no injury could be detected, but ten days later the leaves had fallen badly from the trees sprayed with samples containing the larger amounts of free arsenious oxid without lime. At about the same time the injury began to appear on the trees where lime had been used, though not so marked as in the other case. Rain had fallen in the meantime, and the injury became much more apparent thereafter. The trees sprayed without lime all lost a great many of their leaves, those in which the samples contained the most free arsenious oxid suffering worse. The tree sprayed with the sample containing 8 per cent. of free arsenious oxid lost nearly all of its leaves, and by midsummer many of the branches were dead. A few shoots which bore healthy leaves were springing up from near the base of the branches. Whether the tree will survive, remains to be seen. Lime reduced the injury, but did not wholly prevent it. At midsummer there was a marked difference in the color and vigor of all sprayed trees as compared with adjacent ones not sprayed.

Under general conditions, it seems unwise to spray peaches in leaf with either Paris green containing free arsenious oxid, or with Bordeaux mixture of regular strength. Fortunately, the most serious enemies of the peach can be controlled by spraying when the trees are dormant. Similar tests with Paris green were made upon apple and pear trees. Some injury was noticeable where large amounts of free arsenious oxid occurred in the material, but this was not serious and was nearly all prevented when lime was added.

STRAWBERRY SEEDLINGS.

It seems unwise to give a detailed report of work with strawberries since last year. The progress of seedlings grown from last year crosses was hindered by the fact that it was necessary to allow the small greenhouse to freeze during the winter, owing to a scarcity of fuel. As a result of this, many plants were lost and others were retarded in their growth. For the same reason further work in crossing was prevented with older plants which had been potted for crossing during the winter. These embraced seedlings which had proved promising in 1902 and a few plants of old varieties which promised good combinations for future crosses.

Plants of the same varieties which had been set in the open ground for fruiting did not develop sufficiently to warrant crossing in the field in the spring of 1903. A large number of the plants produced from seeds of the crosses made in 1902 have been planted in the field and are doing well. In the planting of this year all seedlings are placed four feet apart and will be allowed to form runners; but these runners will be kept from intermingling so that it will be possible to observe more fully the behavior of individuals without further selection and transplanting.

The season of 1903 was an unusually poor one for strawberries at the Station. The weather during the early part of the season was unusually dry; then about as ripening began it became very rainy, so that great numbers of the berries rotted on the vines. This rot was caused by a mildew which had the appearance of being the ordinary brown rot of stone-fruits, but no botanical determinations were made to identify the fungus. Notes were made on the behavior of those seedlings which seemed promising at fruiting time. Ten plants were selected from each of these and set on the plain. These plants may not all prove true to the type desired, since in the early planting of seedlings not enough space was allowed between the plants to prevent them from running together.

It seems unwise to discard these seedlings on the behavior in such a year as 1903; hence the rows are to be cut down, thinned out, and left for another season's fruiting. It may be said that some of the seedlings appeared much more promising in 1903 than plants of popular varieties growing in the same field, though most of those varieties were fruiting for the second year and perhaps did not show at their best. The few varieties which have been used in selection experiments were growing under the same conditions as the seedlings, but appeared less promising than some of the better seedlings. One or two in particular held out very late in fruit, a point for which we have been striving.

TREATMENT DESIGNED TO ADD TO THE DURABILITY OF POSTS.

It being necessary to retrellis the vineyard at the College in the spring of 1903, it was determined to put the posts used to different tests, in order that as time goes on some light may be thrown on the value of treating posts to increase durability. The posts used were chestnut, cut in the spring, and were therefore green at the time of setting. The rows as designated run from west to east. The first row at the north was set without treatment of any kind, but half of them were set with the top end down and half with the bottom end down to determine the influence of this factor. It is believed by many that posts set with the top end down last longer, the apparent reason being that moisture moves upwards from the soil less readily if the post is reversed in setting. This same plan of alternating the two ways of setting was also followed in all the different methods of treatment. As obtained, the posts were rounded, running from five to seven inches in diameter at the smaller end. A few were halved for comparison.

In the second row the end of the post to be set in the ground was charred by placing it over a fire until thoroughly blackened and somewhat burned. This proved to be one of the most convenient methods of treatment, so far as the actual work of preparation was concerned. A fire between two logs or rows of stone makes it a simple matter to char the posts sufficiently for this purpose. (*Fig.* 7.) The charred portion extends six inches or more above the top of the ground.

The posts in the third row were painted with hot coal tar, a common and comparatively simple method of treatment. Those in row four were painted in the same manner with hot pine tar. This proved to be a troublesome task, the tar being so thick and so liable to take fire, if overheated, that it was slow and troublesome work to apply it.

Those in the fifth row were treated with lime in the following manner: A pit was dug deep enough to take the posts in as far as they would be set in the ground. In the bottom of this pit was placed a layer of fresh lime, upon which the posts were set. The spaces between them were then filled with lime as well as possible, and water added to cause it to slake. (*Fig.* 8.) This operation, though apparently simple, proved to be both troublesome and expensive. It took nearly a barrel of lime to treat less than twenty posts, and even then not enough was used. It was supposed that it would swell sufficiently in slaking to fill the pit, but this did not occur; consequently the treatment did not reach so high on the posts as it should have done, and as set the top of the ground comes above the line of treatment. The theory upon which this treatment has been suggested is that the heating of the lime in slaking will drive out the moisture of the post and that as it afterwards cools the lime itself will be drawn into the pores, thus impregnating the wood.

The posts used in row No. 6 were allowed to soak over night in a solution of copperas (iron sulfate), then dipped in lime water, in which they were allowed to stand for some time. The argument for this method of treatment is that the copperas and the lime formed a chemical compound which aids in preserving the wood.

Those in the seventh row were treated with carbolineum, one of the proprietary wood preservatives on the market. This proved to be a very simple preparation to apply, it being thin enough so that at ordinary summer temperatures it can be quickly applied with a brush.

The accompanying diagram shows the complete plan of treatment:

Diagram of Vineyard Trellis.

North.

Row 1. Untreated	..	1	4	3	5	3	2	1	2	1	2	3	4	3	2	1	2
Row 2. Charred	1	4	4	3	5	3	2	1	2	1	2	3	4	3	2	1	2
Row 3. Hot coal tar	..	1	4	3	5	3	2	1	2	1	2	3	4	3	2	1	2
Row 4. Hot pine tar	..	1	4	3	5	3	2	1	2	3	2	3	4	3	2	1	2
Row 5. Lime	..	1	6	3	5	3	2	1	2	3	2	3	4	3	2	1	2
Row 6. Copperas and lime	..	..	2	3	5	3	2	1	2	3	2	3	4	3	7	1	2
Row 7. Carbolineum	..	..	..	1	5	3	2	1	2	3	2	3	4	3	2	1	2

South.

1 round post, bottom end down.
2 round posts, top end down.
3 split posts, bottom end down.
4 split posts, top end down.
5 split posts, sharpened, top end down.
6 split posts, charred, top end down.
7 split posts, squared, top end down.

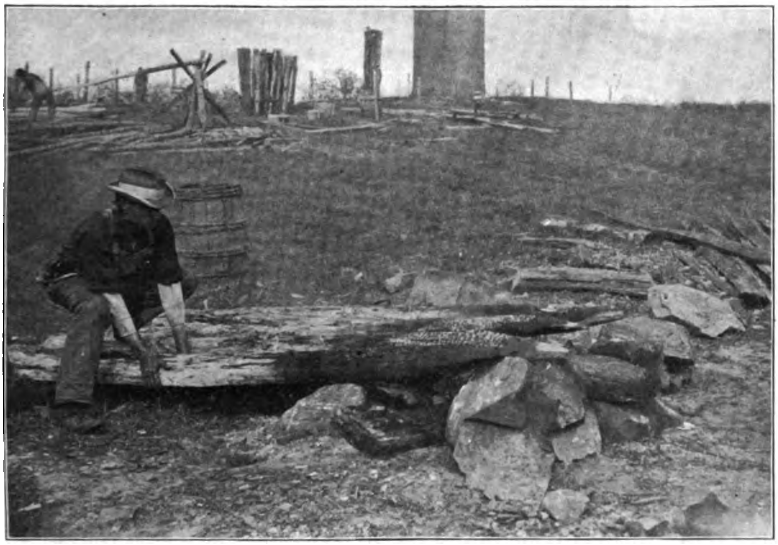

FIG. 7.
Charring Posts. (The camera fails to show the fire.)

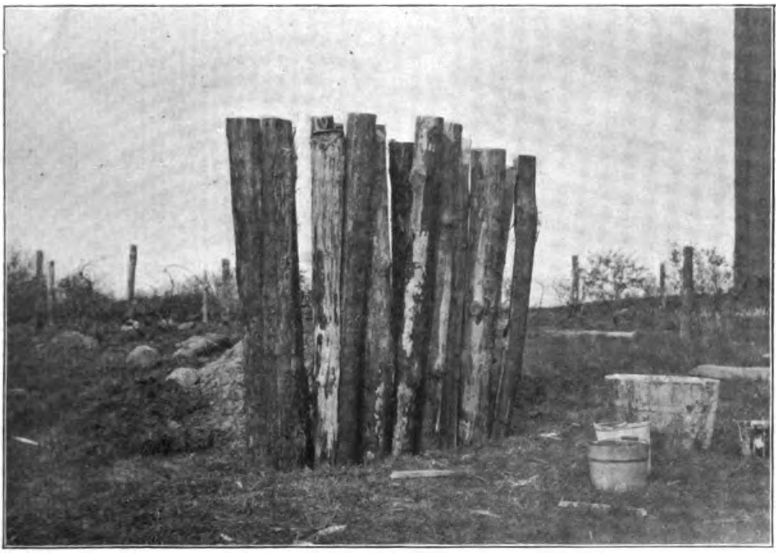

FIG. 8.
Treating Posts with Lime.

UNIV. OF MICH.

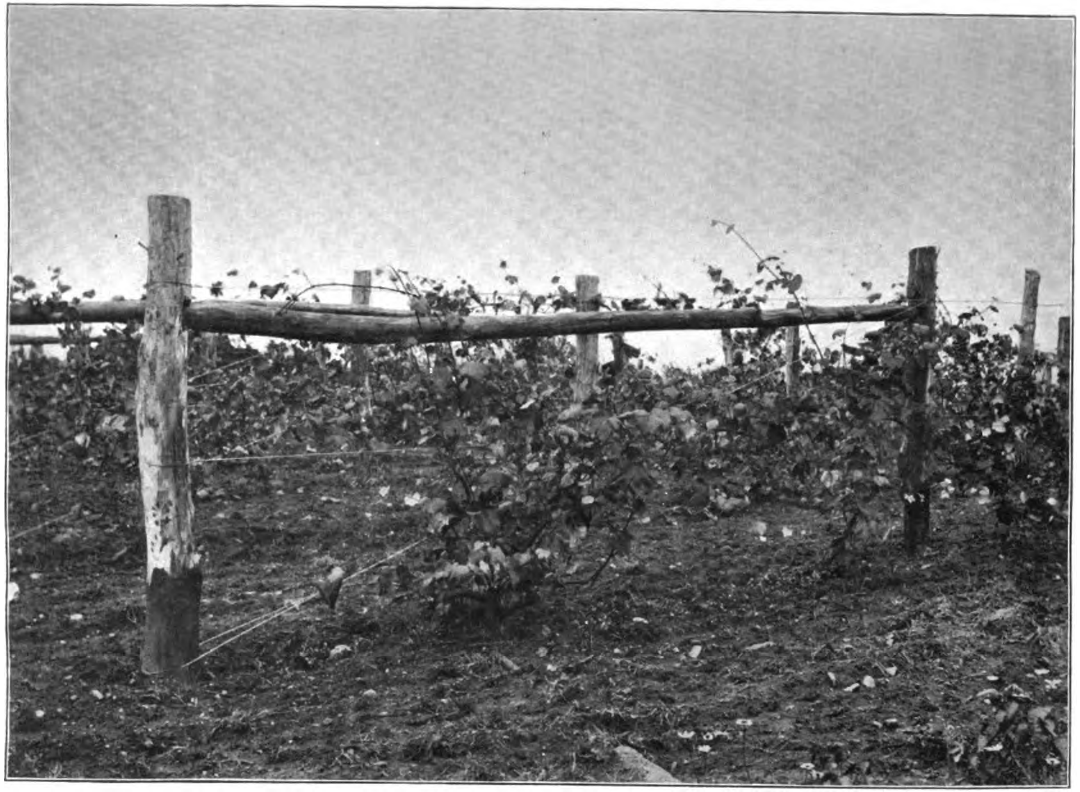

Fig. 9.—Method of Bracing Posts.

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Fig. 9 shows the method of bracing the end posts.

In all trellis work on fencing it is of the utmost importance to have the end post solid. Many methods of bracing have been suggested. The one here used is certainly one of the best and is the most satisfactory plan which the writer has seen. The brace pole extends from the top of the end post to the top of the adjoining one. A strong wire is then passed around the top of the bracepost and the bottom of the end post, drawn as tightly as possible, then tightened by twisting the two wires together until they are perfectly taut. To prevent turning of the end post, thus loosening the wires, alternating wires may be stapled to the opposite sides of the end post, or all wires may be looped around it so as to draw from the center, or a plank may be spiked to the bottom of the post underneath the ground.

Three spikes were driven part way into each post near the bottom to see if they would have a tendency to prevent heaving by frost.

Since the author may never be permitted to report upon the results of this test, it seems best to make a full report of the plan of treatment at this time so that the results can be observed by any one as time goes on.

CHEMICAL AND AGRICULTURAL DIVISIONS.

MISCELLANEOUS ANALYSES.

For the Two Years Preceding July 1, 1903.

B. L. HARTWELL, A. W. BOSWORTH, AND J. W. KELLOGG.

DRIED BLOOD.

	Per cent. I.	Per cent. II.	Per cent. III.
Nitrogen	13.62	9.69	9.58

AMMONIUM SULFATE.

	Per cent. I.	Per cent. II.
Nitrogen	20.83	19.33

NITRATE OF SODA.

	Per cent. I.	Per cent. II.	Per cent. III.	Per cent. IV.
Nitrogen	16.10	15.94	15.18	15.34

TANKAGE.

	Per cent. I.	Per cent. II.	Per cent. III.	Per cent. IV.
Insoluble phosphoric acid	*	6.05	*	*
Total phosphoric acid	11.82	12.16	14.10	*
Nitrogen	7.35	6.11	3.83	7.08

WOOL WASTE.

	Per cent.
Water	35.57
Organic matter	10.67
Nitrogen	0.32

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* Not determined.

I Horn meal.
II Hoof meal.
III Acid fish.
IV Star fish.

	Per cent.			
	I.	II.	III.	IV.
Nitrogen in air-dried material	14.50	14.88	9.22	5.07

DISSOLVED BONE.

	Per cent.
Soluble phosphoric acid	10.10
Reverted " "	4.32
Insoluble " "	0.47
Total.. " "	14.89
Nitrogen	2 43

DISSOLVED BONE-BLACK.

	Per cent.	
	I.	II.
Soluble phosphoric acid	11.72	14.72
Reverted " "	2.61	2.72
Insoluble " "	3.81	1.66
Total " "	18.14	19.10

I Double superphosphate.
II and III Acid phosphate.
IV Raw aluminum phosphate.

	Per cent.			
	I.	II.	III.	IV.
Soluble phosphoric acid	31.98	10.44	*	*
Reverted " "	8.90	3.21	*	*
Insoluble " "	0.12	0.96	*	*
Total	41.00	14.61	16.00	40.32

MURIATE OF POTASH.

	Per cent.	
	I.	II.
Potassium oxid (potash)	49.74	49 46

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* Not determined.

SULFATE OF POTASH.

	Per cent. I.	Per cent. II.
Potassium oxid (potash)	49.59	50.22

AIR-SLAKED LIME.

	Per cent. I.	II.	III.	IV.	V.	VI.	VII.
Calcium oxid (lime)	67.16	75.29	71.61	76.47	59.43	78.19	67.62

DRIED DISTILLERS' GRAINS.

	Per cent. I.	II.	IV.
Water	8.37	4.64	6.60
Crude ash	*	1.83	1.61
" cellulose	20.25	20.56	12.97
" fat	6.40	14.01	12.78
" protein	*	32.13	33.13
Nitrogen-free extract	*	26.83	32.91
		100.00	100.00

TIMOTHY HAY.

	Per cent.
Water	8.25
Crude cellulose	36.29
Crude fat	1.84
Pentosans	24.71

I Buffalo Horse Feed.
II Buffalo Poultry Feed.
III Buffalo Creamery Feed.

	Per cent. I.	II.	III.
Crude protein	12.50	15.94	19.56
Crude fat	5.02	5.59	5.08

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* Not determined.

I. Mixed Feed.
II. Cotton-seed meal.

	Per cent. I.	Per cent. II.
Crude protein	16.31	42.50

PRECIPITATE FROM THE FIELD'S POINT SEWAGE TANKS OF PROVIDENCE, JANUARY, 1903.

	Per cent.
Water	60.26
Ash	17.47
Nitrogen	0.67
Phosphoric acid (P_2O_5)	0.45
Sulfuric acid (SO_3)	0.33
Potassium oxid (potash)	0.86
Calcium oxid (lime)	4.00
Ferric oxid	2.94
Cupric oxid	2.52

CONCERNING THE FUNCTION OF SODIUM WHEN USED IN NITRATE OF SODA.

H. J. WHEELER, B. L. HARTWELL, AND G. E. ADAMS.[1]

INTRODUCTION.

The question of the agricultural value of sodium has for years furnished a fruitful theme for discussion and contention among practical agriculturists and agricultural chemists. Farmers and gardeners have so often observed benefit from its application to the soil in the form of common salt that the question of its frequent usefulness either as a direct or indirect manure seems established beyond question. To be sure a soil abundantly supplied with soluble sodium salts would not respond to further applications of them, even if sodium is essential to the growth of plants. Nor would a soil if fully supplied, in assimilable form, with all other elements which plants require, exhibit an indirect manurial action upon the application of salts of sodium; for even if the sodium salts were to set free other essential plant food, the amounts already present would be sufficient to meet the needs of the plants. Thus it may not be surprising, even with the same kind of plants, if sodium salts may prove highly beneficial upon certain soils and useless or even positively harmful upon others. It is possible also that upon a given soil sodium salts may prove helpful at one time and not at another, even with the same kind of plant.

Marked evidence is already at hand, and further data are being accumulated at this Station, showing that the benefit to be derived from sodium salts is not only dependent upon the soil, the kinds and amounts of supplementary manures employed, but also upon the kind of plants to be grown.

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[1] The authors are indebted to Mr. N. L. C. Moore and Mr. J. B. Spears for the care of the details of the pot experiments, each for one season.

Below are given citations from a few standard works published at various intervals, together with one or two references to articles which have appeared in periodicals, merely to give the reader an idea of the past and present status of the sodium question.

Mulder[1] cites experiments conducted by Chatin, in 1854, showing that sodium salts were not found helpful to barley, oats, spinach, and cress, even though potassium salts were useful in each instance. In the ash of the plants more potassium than sodium was present, even notwithstanding that more of the latter than of the former was applied.

L. von Wàgner.[2] speaking of sodium chlorid (common salt), states that it acts only as an indirect manure by virtue of its setting free other essential elements.

Contejean and Guitteau[3] cite certain groups of plants that contain much soda and others that contain but little. In speaking of maritime plants they say that they take up soda through tolerance rather than necessity. In support of this they claim that certain parts of plants may contain no sodium, but that potassium is found in all portions of them. In conclusion they add that it would seem that sodium cannot perform the function of potassium.

Hübener[4] remarks that it cannot be safely asserted whether sodium is necessary as a food for plants, but that its influence upon the formation of seed cannot be mistaken.

Vines[5] asserts that sodium cannot serve as a substitute for potassium in the nutrition of plants. He refers to analyses of oat plants, and cites the small quantities of sodium present as an indication of its uselessness.

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[1] Die Chemie der Ackerkrume, Berlin, 1863, Vol. 3, p. 71.

[2] Pflanzen-Produktions-Lehre, Buda Pest, 1874, p. 335.

[3] Comptes Rend. (1878) 86. p. 1153.

[4] Schulze's Lehrbuch der Chemie, Leipsig, 1881, Vol. 2, p. 37.

[5] Lectures on the Physiology of Plants, Cambridge, England, 1886, p. 136.

Sachs[1] says that sodium is superfluous in nutrition.

B. Dyer[2] records a beneficial action of common salt "as a dressing for cabbages when a sufficiency of other suitable manurial ingredients is present."

Griffiths[3] cites the same results in support of the beneficial action of common salt.

Storer[4] is of the opinion that sodium cannot take the place of potassium in the organization and translocation of starch. He further adds[5] that "the old notion that soda could replace potash in the plant has been disproved." Storer is of the opinion that crops grow perfectly well without sodium, or that they may obtain enough from the supplies in the soil or even in the air. He considers it accidental rather than essential, but states that common salt acts an as indirect manure.

According to Salm-Horstmar[6] sodium is advantageous for wheat, oats, and barley, but is necessary only for perfecting the grain, for which purpose a minute amount is sufficient.

Müntz and Girard[7] are of the opinion that sodium is, in general, not necessary to the existence of plants, and that it cannot replace potassium. They recommend its use only in connection with the rations fed to the farm animals.[8]

Aikman[9] mentions that sodium in minute quantities may be essential to plants, but states elsewhere that it is in all probability not an absolutely necessary plant-food,[10] nor is it probably required by strand plants. He considers, however (p. 465), that "the action of common salt is probably more complicated than that of any other manurial substance."

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[1] Lectures on the Physiology of Plants, translated by Ward, Oxford, 1887, p. 286.

[2] Jour. Royal Ag. Soc. England, 1887, p. 429.

[3] A Treatise on Manures, London, 1889, p. 256.

[4] Agriculture 2 New York, 1889, p. 155.

[5] Ibid, p. 161.

[6] Versuche u. Resultate ueber die Nahrung d. Pflanzen, pp. 12, 27, 29, and 36, cited by Johnson, How Plants Grow, N. Y. 1891, p. 188.

[7] Les Engrais 1, Paris, 1891, p. 36.

[8] Ibid, 3, p. 154.

[9] Manures and the Principles of Manuring (1894), p. 55.

[10] Ibid, p. 466.

A. Mayer[1] states that sodium does not seem to be essential for certain plants, but conservatively gives a warning against an application of this idea to plants in general; for, by virtue of the large amounts of sodium which some of them contain, he suggests that they either require some sodium, or that they may be benefited in some way by it.

Strasburger, Noll, Schenck, and Schimper[2] say that "Potassium, unlike sodium, is essential to plant life."

An unusual and renewed interest in the soda question has been awakened by the investigations conducted by Atterberg[3] and by P. Wagner and Dorsch.[4]

Atterberg's experiments were conducted with oats grown in pots filled with quartz sand. In one series of experiments portions of the potash were replaced by soda and in the other by lime, no soda having been applied in the series where lime was introduced. From the results the author concludes that, in case of a deficiency of potassium, sodium may perform important functions, and that it cannot, therefore, be looked upon as a useless plant constituent. He further adds that the application of common salt to the soil is shown to be rational from a scientific standpoint, and that the sodium salts associated with the German potash salts should not be regarded as useless, but as possessing certain value for the nutrition of plants.

Wagner and Dorsch also speak in no uncertain manner of the value of sodium salts,[5] for as a result of two years' experiments with carrots and one year's experiments with barley, they conclude that it is shown beyond doubt that sodium is able to exert a marked influence upon the development of plants, and that cultivated plants supplied with identical amounts of potassium produce a yield nearly half as great again, if manured with sodium chlorid (common salt). In view of these data being presented by such well-known and eminent European investigators, it is not surprising that it seemed necessary to renew the study of the influence of sodium upon the physiological functions of plants, and of the bearing of this element upon general agricultural practice. More recently M. Stahl-Schroeder[1] has criticised the results just cited, and comes to the conclusion, claimed to be sustained by experiments of his own, that the beneficial action of the sodium in the experiments by Atterberg and by Wagner and Dorsch was probably chiefly, if not wholly, due to the liberation of potassium from the soils which they employed in their experiments. Still more recently Jordan and Jenter[2] have experimented with barley, tomatoes, and peas. Their experiments were conducted in galvanized iron pots filled with pure quartz sand. They conclude, so far as their experiments throw light upon the question, that sodium cannot perform the function of potassium, though where sodium was largely substituted for potassium in the manures a greater quantity of it and a smaller amount of potassium was found in the plants than under other conditions.

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[1] Lehrb. d. Agrikulturchemie 1, Heidelberg, 1895, p. 283.

[2] A Text-book of Botany. Translated by Porter, London and New York, 1898, p. 173.

[3] Deut. Landw. Presse, 1891, p. 1035, Abstract in E. S. R. 3, p. 554.

[4] Die Stickstoffdüngung d. Landw. Kulturpflanzen, Berlin, 1892, pp. 227–242.

[5] Ibid, p. 237.

These writers point out an instance in which the "peas grew as rapidly and matured as fully with .146 gram of potash per pot as with 1.462 grams" (p. 349).

Sufficient has been said to show that a thorough solution of the sodium problem has not yet been reached, and that in the interest of agriculture the question should receive careful and systematic study. Unfortunately, the very nature of the problem is so complex that its final solution can only result from repeated and long-continued inquiry, possibly with many different kinds of plants. The investigation of this question at this Station was begun in 1894, portions of which, relating to one or two phases of the subject, have already been published in Annual Reports[1] of the Station. It is proposed at this time to place on record certain additional results which it is hoped to further supplement in the near future by other field, pot, and laboratory data.

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[1] Jour. f. Landw. 47 (1899), pp. 53-57.

[2] Bul. 192, N. Y. Ag. Ex. Sta., Dec. 1900.

POT EXPERIMENTS BEARING UPON THE QUESTION OF THE MANURIAL ACTION OF SODIUM AS AN EXPLANATION OF THE SUPERIORITY OF NITRATE OF SODA OVER SULFATE OF AMMONIA.

P. Wagner and Dorsch[2] in their discussion of this question state that, especially in the case of the root crops (which stand in marked need of potash), such as sugar beets, fodder beets, and potatoes, manuring with ammonium salts has given results far inferior to those secured with an equivalent amount of nitrogen in nitrate of soda.[3] They add that experiments conducted under the direction of Maercker have shown the same result, but that nowhere has an explanation of the fact been attempted. Like results having been obtained in their own experiments, they claim that the difference in the manurial value of the two salts is attributable to the sodium content of the nitrate of soda and to the energetic action of sodium in increasing the effectiveness of the potassium by virtue of its own direct influence upon the development of cultivated plants (p. 238). It is evident, therefore, that they were fully convinced that the sodium had acted as a direct manure. In further support of their idea, experiments showing the superiority of nitrate of soda over sulfate of ammonia, conducted by Samek,[4] Baessler[5] and at Rothamstead[6] are cited, and in each instance Wagner and Dorsch find a ready explanation for the superiority of nitrate of soda upon the assumption that it acted as a direct manure. They point out the fact that Baessler's results with barley agree with Maercker's experience with the same plant in showing a greater superiority of nitrate of soda over sulfate of ammonia than is exhibited by any of the other cereals. This again finds ready explanation by Wagner and Dórsch, who assert that by their own experiments it has been shown that barley is more in need of potash manuring than oats, presumably owing to the former possessing inferior power to extract potash from soils. Since, as they claim, barley stands in such great need of potash as compared with oats, it is in consequence more thankful for sodium for the reason that by its use it can make the limited potash supply more effective than otherwise.

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[1] See Seventh An. Rep't (1894), p. 168; Eighth An. Rep't (1895), p. 215; Ninth An. Rep't (1896), p. 221; Tenth An. Rep't (1897), p. 226; Eleventh An. Rep't (1898), pp. 133 and 137; Twelfth An. Rep't (1899), p. 174.

[2] Die Stickstoffdüngung d. Landw. Kulturpflanzen, Berlin, 1892, pp. 227–242.

[3] Compare tabulated results by Stutzer, Der Chilisaltpeter, Berlin, 1886, pp. 97, 98.

[4] Tyroler landw. Blätter, 7 (1889), No. 2, pp. 14, 15, cited from Wagner and Dorsch. Abstract in Biedermann's Central-Bl. f. Ag. Chem. 18 (1889), p. 282.

[5] Wochens. d. Pomm. oek. Gesell. 1888, also No. 22, pp. 270, 271, No. 13, pp. 163, 164, cited from Wagner and Dorsch. Abstract in Biedermann's Central-Bl. f. Ag. Chem. 188 (1889), pp. 14–17.

[6] Warington reprint from Gas Engineer's Annual for 1889, cited from Wagner and Dorsch.

It seems desirable at this point to refer to certain field experiments, conducted at this Station, which seem to have an important bearing upon the conclusions drawn by Wagner and Dorsch.

In 1893 four adjacent tenth-acre plots of exceptionally uniform character, as shown by trials of Indian corn (maize) without manure, were selected for experiments with nitrate of soda and sulfate of ammonia. All have received like treatment throughout so far as concerns the quantities of muriate of potash, dissolved bone-black, and magnesium sulfate applied. Two plots received nitrogen in sulfate of ammonia (Nos. 23 and 25), and two an equivalent amount in nitrate of soda (Nos. 27 and 29). One plot in each group was limed at the same rate[1] (Nos. 25 and 29). All of the other conditions of the experiment were identical, the number of plants set upon each plot and the quantities of seed planted were alike in all cases, so that the differences observed might not be attributable to other factors than those being particularly studied. These experiments have been continued without interruption from 1893 to 1903, inclusive, and embrace trials of about 200 different kinds of plants.[1] It should be stated that more marked exhibitions of the varying soil and manurial requirements, and of the varying adaptability of different kinds of plants to given conditions, were probably never observed in field experiments.

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[1] Viz. 5,400 pounds of air-slaked lime per acre in 1893 and 1,000 pounds per acre in 1894. Subsequent applications were not made.

The physical character of the soil, as shown by an examination conducted under the direction of M. Whitney,[2] was such as Whitney assigns to early "truck" or market gardening soils. Below the eight to ten inches of surface soil lies a yellow loam succeeded occasionally by a little clay, and at a depth of 24 to 27 inches by alternating layers of sand and gravel to an unknown depth.

Both surface soil and subsoil were decidedly acid, as shown by their action upon blue litmus paper. A considerable percentage of the humus was directly soluble in ammonium hydroxid without previous extraction with hydrochloric acid. The fact that only minute amounts of carbon dioxid were eliminated upon heating the soil with distilled water, but that large amounts were driven off upon the introduction of calcium carbonate with the water, showed that the soil was practically devoid of calcium carbonate (carbonate of lime), though containing more than 0.5 per cent, of calcium oxid removable by hydrochloric acid (Hilgard's method).

With but few exceptions the plants upon the unlimed nitrate of soda plot were invariably far superior to those upon the unlimed plot which received sulfate of ammonia. Striking exceptions to this were exhibited by flax, the watermelon, the blue lupine, and common sorrel (*Rumex acetosella*). The yield of lupine was less than one-fourth, and of the sorrel but a little over one-third, as great upon the plot manured with nitrate of soda as upon that which received sulfate of ammonia.[3] Lettuce, spinach, beets, muskmelons, onions, asparagus, and certain other plants, on the contrary, nearly all died upon the unlimed plot which received sulfate of ammonia. Upon the unlimed plot receiving nitrate of soda, however, though a few of these plants died, a most striking difference in its favor was always noticed.

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[1] See the Annual Reports of the R. I. Ag. Exp. Sta. from 1893 to 1899, inclusive; also Bul. No. 69, April, 1901, and Bul. No. 96, September, 1903.

[2] Bul. 47, U. S. Dept. of Ag., Div. of Chem., p. 44; also Bul. No. 57, U. S. Dept. of Ag. Div. of Chem., p. 81.

[3] Compare other experiments by Wheeler and Tillinghast (Bul. 66, R. I. Ag. Ex. Sta., April, 1900, p. 145), in which, upon a nitrate of soda plot, the common sorrel amounted to 4 per cent. of the total crop; while with sulfate of ammonia it amounted to 48.7 per cent.; like amounts of nitrogen having been used in each instance.

Those plants which were unable to withstand the conditions upon the unlimed sulfate of ammonia plot were invariably wonderfully helped by liming, even where nitrate of soda was employed. As concerns the two limed plots, blackberries have succeeded better upon the one receiving sulfate of ammonia than upon that treated with nitrate of soda.

As a result of many trials of carrots, barley, wheat, oats, and rye, but little, if any, advantage of nitrate of soda over sulfate of ammonia was noticeable after the second application of lime had been made. In the case of lettuce, spinach, beets, onions, poppies, asparagus, and certain other plants a very marked advantage of the limed plot receiving nitrate of soda over the limed plot to which sulfate of ammonia was applied was always noticed. Another striking feature of the results was that these were the very plants which failed to grow upon the very acid unlimed plot (No. 23), where sulfate of ammonia was applied; they were therefore among the plants which exhibited the greatest benefit from liming in connection with both sulfate of ammonia and nitrate of soda.

Applying the reasoning of Wagner and Dorsch, in relation to the relative effectiveness of nitrate of soda and sulfate of ammonia in the European experiments, to the data obtained in the case of the two limed plots just mentioned, one must assume that the plants which showed such marked differences did not find at their disposal a sufficient amount of potash,[1] and for this reason the sodium of the nitrate of soda, acting as a direct manure, enabled them to come nearer than they otherwise would to producing a maximum crop. The same reasoning would apply with equal force in a comparison of the unlimed plots upon which similar comparisons of nitrate of soda and sulfate of ammonia were made. This argument in connection with the unlimed plots loses, however, much of its force when it is remembered that far larger crops were obtained in every instance from the limed than from the unlimed nitrate of soda plot, notwithstanding that the quantities of potassium and sodium per plot were identical in both instances. The critic objecting to this point will argue that the lime had acted as an indirect manure and liberated potash and soda so that greater amounts of these substances actually stood at the disposal of the plants upon the limed plot.[1] This objection, which from a chemical standpoint might under some circumstances appear perfectly reasonable, also loses much of its force when it is stated that in another series of experiments,[2] upon similar land in close proximity, evidence was furnished, by the simultaneous exhaustion of potash from both limed and unlimed plots by successive cropping without potassic manures, that the quantity of these alkalies probably liberated by the lime must in this experiment have been too small to have produced the results which have been obtained every year from 1894 to 1903, inclusive. It might also be objected that nitrification was not active upon the limed plot which received sulfate of ammonia and that the plants which grew there did not find at their disposal a sufficient amount of nitric nitrogen. Militating against this idea, however, stands the fact that the cereals, millet, and certain other plants standing naturally in great need of nitrogen apparently found at their disposal upon that plot all of the nitric nitrogen required to make an ideal growth. Furthermore, actual trials of the nitrifying power of cultures from the limed plot manured with sulfate of ammonia gave indications that they were not inferior in activity to those from the limed plot which received nitrate of soda.[1] In fact, repeated study of these experiments led to the idea that possibly the difference in the yield of certain plants, when grown by the aid of nitrate of soda on the one hand and of sulfate of ammonia on the other, might be due in some measure to the *difference in the chemical reactions of the soil induced in the first instance by the soda left behind by the nitrate of soda, and, in the second instance, by the sulfuric acid (oil of vitriol) remaining from the sulfate of ammonia.*[2] This seems even more probable when it is stated that in the European experiments,[3] the advantage of nitrate of soda over sulfate of ammonia was greater with beets of various kinds than with the cereals. A further point in favor of such a conclusion is the fact that in experiments in various sections of Rhode Island[4] it has been found that beets are more seriously affected than barley by a lack of carbonate of lime and the consequent acidity of the soil. This is a factor which Wagner and Dorsch have left entirely out of consideration in the discussion of their own and other European results; the entire difference having been attributed by them to the ability of the soda, acting in a direct manurial capacity, to supplement a limited potash supply and make it capable of producing a larger yield than it could if soda were absent. In order to test this question in such a may as to throw direct light upon the field experiments which have just been referred to, it was decided to make trials by way of pot culture, employing the same soil which was used in the field. To this end soil was selected from the two limed plots, one receiving sulfate of ammonia (No. 25), and the other nitrate of soda (No. 29). The pots were of the Wiley pattern, having an area of 108.43 square inches, and were constructed of galvanized iron. The pots of series A, C, D, E, F, and G were filled with soil from the limed plot which was manured with sulfate of ammonia, and those of series B with soil from the limed plot which received nitrate of soda. Each pot in the seven series received like amounts of dissolved bone-black, magnesium sulfate, and chemically pure potassium chlorid.[1] Each pot in all of the series but B received sulfate of ammonia, but in series B nitrate of soda was supplied. The rates at which these materials were applied were such that the amount of nitrogen per pot in each series was identical. The experiment was begun in the spring of 1897, the two plots of land from which the soils were taken (Nos. 25 and 29) having already received four annual dressings of sulfate of ammonia and nitrate of soda, respectively. The nitrate of soda had been applied previously in the field at the rate of 465 pounds per acre, annually. The quantities of sulfate of ammonia were varied according to the composition of the two salts so as to furnish the same quantity of nitrogen as was supplied by the nitrate of soda. Such conditions having prevailed, it seemed reasonable to suppose, if the differences between the results with nitrate of soda and sulfate of ammonia were due wholly to a manurial action of the sodium of the nitrate of soda, that applications of sodium salts to the soil of the plot receiving sulfate of ammonia ought to enable it to give results equal to those secured where nitrate of soda had been employed. Again, if the sodium had been efficacious as an indirect manure by virtue of its having liberated potash from zeolitic or other easily decomposable compounds in the soil, it would then be reasonable to expect that an application of a potassium salt would raise the yield produced by sulphate of ammonia approximately to that obtained by nitrate of soda. Furthermore, in view of the fact previously cited, that the amount of potash apparently liberated from the Kingston soil by lime is small and that a heavy, succeeded by a lighter, application of air-slaked lime had been made in the years 1893 and 1894, it would seem highly probable, in case carbonate of lime were capable of raising the yield from the soil receiving sulfate of ammonia approximately to that where nitrate of soda was used,

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[1] For the first two years 180 pounds and later 300 pounds of muriate of potash were applied per acre annually.

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[1] It was found that orchard grass grown upon the limed plot which received nitrate of soda contained but 3.978 per cent. of potassium oxid in the dry matter as compared with 4.129 per cent. in the dry matter of the grass grown upon the unlimed plot.

[2] See experiments on the Substitution of Soda for Potash, An. Rep'ts of the R. I. Ag. Ex. Sta., from 1894 to 1899.

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[1] Experiments conducted through the courtesy of Dr. H. W. Wiley of the U. S. Dept. of Agriculture, Thirteenth An. Rep't R. I. Ag. Ex. Sta., 1900, p. 321.

[2] Compare Prianischnikow, Chem.-Zeit. 24 (1900), No. 66, p. 701.

[3] Stutzer, Der Chilisaltpeter, Berlin, 1886, pp. 97, 98.

[4] Ninth An. Rep't R. I. Ag. Ex. Sta. (1896), pp. 282–293.

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[1] The potash salt in ordinary muriate of potash.

that this result had not been chiefly by virtue of its action as a liberator of either soda or potash, but owing to its action as a direct manure[1] or as a neutralizer of the sulfuric acid left behind by the sulfate of ammonia. In case the last view were the correct one, it would seem probable that sodium carbonate would act more favorably than sodium chlorid (common salt) or sodium sulfate (Glauber's salt). This was the basis of the reasoning that led to the plan of experiment here indicated in condensed form, viz.:

Soil from the plot manured with nitrate of soda.	Series B received nitrate of soda.
Soil from the plot manured with sulfate of ammonia.	“ A ” sulfate of ammonia. “ C ” sulfate of ammonia and calcium carbonate. Series D received sulfate of ammonia and sodium chlorid (common salt). Series E received sulfate of ammonia and sodium sulfate (Glaubers' salt). Series F received sulfate of ammonia and sodium carbonate (soda ash). Series G received sulfate of ammonia and c. p. potassium chlorid.

The materials and the quantities of the same applied to each of the thirty pots in the experiment were as follows:

6.2730 grams dissolved bone-black. (800 pounds per acre.)
3.1365 grams magnesium sulfate. (400 pounds per acre.)
2.7444 grams c. p. potassium chlorid. (350 pounds per acre.)

The pots of series B received nitrate of soda at the rate of 3.629 grams per pot (equivalent to 465 pounds per acre), and to those of series A, C, D, E, F, and G sulfate of ammonia was applied at the rate of 2.7584 grams per pot, a quantity supplying to each the same amount of nitrogen as was contained in 3.629 grams of the nitrate of soda.

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[1] This view regarding the direct action seems hardly tenable, owing to the content of lime in various combinations already in the soil (mentioned elsewhere) and on account of the amounts contained in the annual applications of dissolved bone-black. Furthermore, the soil was capable of producing many successive crops of maximum size of those plants which thrive well upon acid soil, even notwithstanding the fact that many of them remove large amounts of calcium from the soil.

In addition to the materials just mentioned, the series of pots filled with soil from plot No 25, which had been manured annually with sulfate of ammonia, received the following kinds and amounts of substances:

Series A. Nothing additional.
" C. 55 grams calcium carbonate (carbonate of lime) per pot (equivalent to about 3 tons of air-slaked lime per acre).
" D. 11.808 grams of c. p. sodium chlorid, requiring 11.900 grams of the pure salt in the natural state of moisture.
" E. 31.695 grams of sodium sulfate (cryst.) (furnishing sodium at the same rate as the sodium chlorid in series D).
" F. 11.533 grams of sodium carbonate in its natural state of moisture (furnishing sodium at the same rate as the sodium chlorid in series D, and the sodium sulfate in series E).
" G. 2.213 grams of c. p. potassium chlorid, equivalent to 2.7444 grams of ordinary muriate of potash (50.66 per cent. K_2O) or at the rate of 350 pounds per acre of the regular manure salt.

The amounts of sodium chlorid, sodium carbonate, and sodium sulfate were such as to furnish to the pots of series D, E, and F sodium enough per acre to equal that which had been applied per acre in nitrate of soda to the plot (No. 29) from which the soil of series B was taken.

The water capacity of the soil was determined and the weights of the pots were taken daily or as frequently as necessary in order to maintain a proper supply of water. Well water containing the equivalent of 9.6 parts of sodium chlorid per million and only a trace of potassium salts was employed of necessity in the experiment.

Table beets were selected for this experiment, for the reason that in other experiments with them at this Station nitrate of soda has always proved superior to sulfate of ammonia when like amounts of nitrogen were applied in each instance. The beets upon harvesting were sliced and dried in the air at ordinary room temperature; subsequently they were dried for an equal length of time in the air at from 65° to 70° C. The weights thus obtained are given below in grams. Unfortunately but few individuals could be grown in each pot, and hence the irregularities in yield; for few plants have been found in the course of our experiments to show greater individuality than beets. The irregularities in growth have always been found to be greatest where the soil conditions are unfavorable, in consequence of which great fluctuations in the yields in a given series have finally come to be regarded in a considerable degree as indicative of unfavorable soil conditions. Weak individuals often fail to make a satisfactory growth even where the conditions are favorable.

Table Showing Weights of Crop in Grams.

Pot Number.	Series A. Sulfate of Ammonia.	Pot Number.	Series B. Nitrate of Soda.	Pot Number.	Series C. Sulfate of Ammonia and Calcium Carbonate.	Pot Number.	Series D. Sulfate of Ammonia and Sodium Chlorid.	Pot Number.	Series E. Sulfate of Ammonia and Sodium Sulfate.	Pot Number	Series F. Sulfate of Ammonia and Sodium Carbonate.	Pot Number.	Series G. Sulfate of Ammonia and Muriate of Potash.
1.......	62.9	7	41.0	13	67.5	19	53.7	22	71.2	25	58.3	28	19.6
2.......	70.7	8	62.7	14	78.0	20	52.5	23	30.3	26	23.9	29	48.3
3.......	46.1	9	66.5	15	64.6	21	45.3	24	56.8	27	61.7	30	52.2
4.......	56.0	10	76.6	16	63.4	..	....	..	....	..	....	..	....
5.......	41.5	11	65.5	17	58.4	..	....	..	....	..	....	..	....
6.......	61.0	12	77.5	18	68.0	..	....	..	....	..	....	..	....
Average per pot..	56.4	..	65.0	..	66.7	..	50.5	..	52.8	..	48.0	..	40.0

From an examination of the foregoing table it will be seen that the individuality of the plants was so important a factor as to permit of no definite conclusions from this experiment, though certain points are suggestive. In series A, where the nitrogen had been supplied in sulfate of ammonia, the average yield was but 56.4 grams, and in two instances it fell below 50 grams. On the other hand, where nitrate of soda had been employed (series B) the average was 65.0 grams per pot, and in but one instance did a yield fall below 62.7 grams. In the series receiving sulfate of ammonia, but to which a generous application of calcium carbonate (carbonate of lime) had been made (series C), it will be seen that a greater uniformity of yield was obtained than in any other series. In this instance the average yield was 66.7 grams, and but one pot produced a yield below 63.4 grams, and even in that instance the low yield was 17.4 grams greater than the smallest yield in the nitrate of soda series (series B). In series D, which received sodium chlorid in connection with sulfate of ammonia, the average yield was 50.5, or below that of any of the preceding series, and the yield of each of the three pots was below any yield but one in the nitrate of soda series (viz., pot No. 7, series B). Again, comparing these results with those secured with sulfate of ammonia without the addition of sodium salts (series A), no advantage—but on the contrary an apparent disadvantage—is seen to have resulted from the use of the sodium salt.

Where sodium sulfate was employed in connection with sulfate of ammonia (series E), the average result was slightly better than with sodium chlorid, but no positive advantage appeared to have been derived from its use. In the instance where sodium carbonate was applied in connection with sulfate of ammonia (series F) the results, excepting that from pot No. 26, were better than from any pot in the sodium chlorid series and better than any pot, excepting No. 22, in the sodium sulfate series.

It is of especial interest to note that a further addition of potassium chlorid in connection with sulfate of ammonia (series G) not only resulted in no benefit but appeared to act injuriously.

Even though it is recognized that these results show too much variation within individual series to be considered conclusive, they are nevertheless interesting and valuable when studied in connection with further data, obtained in 1898, from the same pots and soil.

RESULTS SECURED IN 1898.

Below are given the details of the same experiment for the year 1898. Each pot received the following:

6.273 grams dissolved bone-black.
3.1365 " magnesium sulfate.
2.7444 " c. p. potassium chlorid.

Each pot of series A, C, D, E, F, and G received 2.6618 grams of sulfate of ammonia, and each pot of series B received a like amount of nitrogen in nitrate of soda requiring 3.629 grams of the nitrate containing 15.3 per cent. of nitrogen. Series C, which received calcium carbonate in 1897, did not receive an additional amount in 1898.

Series D received 2.3205 grams of sodium chlorid. It will be remembered that in 1897 the quantity applied was estimated to be sufficiently great to furnish as much sodium as had been applied in the previous years to the soil used in the nitrate of soda series (B).

Series E received 2.8124 grams "anhydrous" sodium sulfate (containing 0.15 per cent. of water) per pot. Series F received 2.0959 grams of absolutely dry sodium carbonate per pot.

The quantity of sodium per pot in series D, E, and F was therefore made identical, and was equal to that applied per pot in the series receiving nitrate of soda (series B).

In Series G each pot received 2.213 grams of c. p. potassium chlorid, equivalent to 2.7444 grams of commercial muriate of potash containing 50.66 per cent. of potash.

Spinach was grown in 1898, for the reason that it, like beets, had always given greater returns with nitrate of soda than with sulfate of ammonia, and because it was hoped that it would show less individuality than beets. Owing to a misunderstanding, the crops from the individual pots were not harvested separately, but the entire crop from each series was secured in a lot by itself. For this reason the comparison of variations in yield within given series is impossible, a fact which would ordinarily be of serious import, but which in this instance does not interfere with drawing satisfactory deductions owing to the enormous differences between the product from the different series. Below are given the average weights of the crop in grams per pot from the different series after drying at 100° C. (See Fig. 1.)

		Average Weight of Crop Per Pot
Series	A. sulfate of ammonia	0.259
"	B. nitrate of soda	4.242
"	C. sulfate of ammonia + calcium carbonate*	3.702
"	D. " " + sodium chlorid	0.000
"	E. " " + " sulfate	0.103
"	F. " " + " carbonate	2.210
"	G. " " + potassium chlorid	0.225

After the removal of the first crop, onions were sown. They, like spinach and beets, have always given better returns on our soil with nitrate of soda than with sulfate of ammonia. Having been sown so late in the season, the plants had time to but partially mature.

No further applications of sodium salts or other materials were made to any of the pots. Below are given the weights of the entire onion plants (only partially developed) obtained from each pot (dried at 100° C).

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* In 1897.

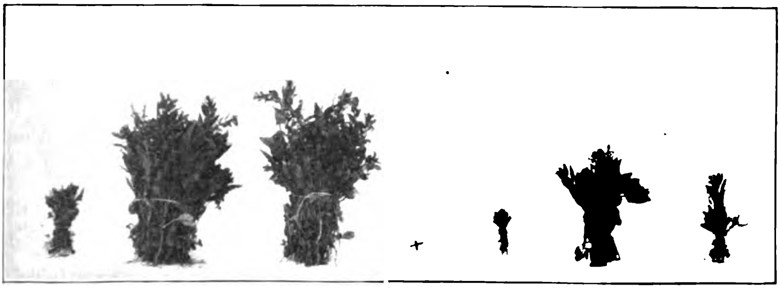

FIG. 1.

Series A. B. C. D. E. F. G.

Series A.—Sulfate of ammonia.
Series B.—Nitrate of soda.
Series C.—Sulfate of ammonia, calcium carbonate.
Series D.—Sulfate of ammonia, sodium chlorid.
Series E.—Sulfate of ammonia, sodium sulfate.
Series F.—Sulfate of ammonia, sodium carbonate.
Series G.—Sulfate of ammonia, potassium chlorid.

Weights of Onions, Entire Plant, Immature (in grams).

Number of Pot.	Series A. Sulfate of Ammonia.	Number of Pot.	Series B. Nitrate of Soda.	Number of Pot.	Series C. Sulfate of Ammonia and Calcium Carbonate.	Number of Pot.	Series D. Sulfate of Ammonia and Sodium Chlorid.	Number of Pot.	Series E. Sulfate of Ammonia and Sodium Sulfate.	Number of Pot.	Series F. Sulfate of Ammonia and Sodium Carbonate.	Number of Pot.	Series G. Sulfate of Ammonia and Muriate of Potash.
1......	9.37	7	18.61	13	11.75	19	1.50	22	2.48	25	11.44	28	6.30
2......	8.55	8	16.10	14	17.27	20	1.40	23	2.14	26	10.59	29	4.35
3......	6.49	9	15.13	15	16.89	21	3.43	24	1.30	27	0.12†	30	5.39
4......	10.30	10	17.06	16	11.84	..	....	..	....	..	....	..	....
5......	7.14	11	11.76	17	17.94	..	....	..	....	..	....	..	....
6......	6.53	12	10.94	18	5.23*	..	....	..	....	..	....	..	....
Average per pot..	8.1	..	14.9	..	15.1	..	2.1	..	2.0	..	11.0	..	5.3

From the foregoing results with spinach it will be observed that the average weight of the crop per pot, where the nitrogen was applied in sulfate of ammonia, was but 0.259 gram, but where the nitrogen in nitrate of soda was applied it amounted to 4.242 grams. Where calcium carbonate was applied in connection with the sulfate of ammonia, the average was 3.702 grams, or in other words it was nearly equal to that where the nitrogen was employed in nitrate of soda. By the use of sodium chlorid in place of the calcium carbonate the plants were entirely destroyed; with sodium sulfate the results were but little better, the average yield of 0.103 gram per pot having been less than in series A without any addition. By the use of sodium carbonate a great advantage was noticed, the average yield having been raised to 2.21 grams per pot, or to nearly ten times that of the pots which received no addition whatsoever. By the addition of potassium chlorid an average yield of 0.227 gram per pot was produced, or slightly less than without an extra addition. From this it will be seen that neither the use of sodium nor potassium salts tended to increase the yield from the soil where the sulfate of ammonia had been used, excepting the single instance of sodium carbonate, which is strongly alkaline and which was capable, like calcium carbonate, of decreasing the acidity of the soil.

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* Badly affected by blight, and omitted from the average.

† Practically destroyed by blight, and omitted from the average.

The results with onions, which were grown as a second crop, fully corroborate those with spinach, to the effect that far greater growth resulted upon the soil which had received nitrate of soda than upon that where sulfate of ammonia had been used. In this instance, however, the use of calcium carbonate in connection with the sulfate of ammonia raised the yield so that it exceeded that where nitrate of soda had been employed. By the addition of the various sodium salts or of potassium chlorid the yield of the soil where sulfate of ammonia had been used was increased in no instance excepting that where sodium carbonate was employed, in which case it rose decidedly.

For the purpose of repeating this experiment in a modified form, pots of the same kind were filled, in 1899, with a new lot of soil which was taken from the same plots as before. Pots Nos. 1 to 4, inclusive, were filled with soil from the limed plot (No. 29) which had received nitrate of soda, and the balance of the pots were filled with soil from the limed plot (No. 25) to which sulfate of ammonia had been added. Each pot contained 72 pounds of soil in its moist condition, and received the following manures:

10	grams	dissolved bone-black.
3	"	magnesium sulfate.
3	"	muriate of potash.

Pots Nos. 1 to 4, inclusive, received nitrogen in nitrate of soda, but at the same rate as the other pots which were manured with sulfate of ammonia. In the former case 4.0 grams of nitrate of soda, containing 15.78 per cent. of nitrogen, and in the latter one 3.048 grams of sulfate of ammonia, containing 20.71 per cent. of nitrogen, were required.

The following table shows the groups of pots and the additional treatment accorded to each:

Group.	Nos. of Pots.	Manured With.	Additional Material Per Pot (grams).
A.....	1–4	Nitrate of Soda.	None.
B.....	5–8	Sulfate of Ammonia.	"
C.....	9–12	" "	70.0000 c. p. Calcium Carbonate.
D.....	13–16	" "	3.7441 " Sodium Sulfate.
E.....	17–20	" "	2.7949 " Sodium Carbonate.
F.....	21–24	" "	25.0000 " Sodium Carbonate.
G.....	25–28	" "	3.0253 " Potassium Sulfate.
H....	29, 30, and 35	" "	2.3997 " Potassium Carbonate.

Groups D and E received quantities of sodium salts furnishing like amounts of sodium, and groups G and H received, likewise, amounts of potassium salts furnishing like amounts of potassium in each case. The materials which were applied were mixed with the entire mass of soil in the pots.

Common spinach was planted in all of the pots on June 2, and on June 22 the plants were thinned so as to leave seven in each pot. Lice appeared upon some of the plants, and these were sprayed with water containing 3 per cent. of kerosene. Most of the plants which were sprayed were somewhat injured by the spray, and all of those in pot 10 were so seriously injured that the pot was discarded from the experiment. In pots Nos. 7, 9, 10, and 26 one plant in each case was eaten off by grubs. On July 12th the spinach was harvested and weighed green. It was subsequently air-dried and finally dried to constant weight at about 100° C. Below are given the weights of the fully dried material from the various pots:

Pot Number.	Grams of dried spinach.		Group.	Materials Applied Other Than Nitrogen and the Regular Manures.
1..................	21.610	(A)	Nitrate of Soda.	None.
2..................	18.405*			
3..................	22.475			
4..................	19.915			
Average............	20.601			

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* This pot contained two plants which were quite small. Not excluded from the average.

Pot No.	Grams of dried spinach.	Group.	Materials applied other than nitrogen and the regular manures.
5	17.323	(B) Sulfate of Ammonia.	None.
6	19.069		
7	18.974*		
8	14.937		
Average	17.576		
9	19.950*	(C) Sulfate of Ammonia.	Calcium Carbonate.
10	†		
11	19.040		
12	19.395		
Average	19.462		
13	21.805‡	(D) Sulfate of Ammonia.	Sodium Sulfate.
14	18.878		
15	17.550		
16	18.041		
Average	19.069		
17	19.899	(E) Sulfate of Ammonia.	Sodium Carbonate. (Small amount.)
18	17.713		
19	15.699		
20	19.440		
Average	18.188		
21	19.500	(F) Sulfate of Ammonia.	Sodium Carbonate. (Large amount.)
22	20.050		
23	19.920		
24	20.776		
Average	20.062		

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* One of the seven plants eaten off, and this weight was obtained by dividing the weight of the remaining plants by six and multiplying by seven.

† Discarded, owing to serious injury to all of the plants by spraying.

‡ One plant was quite small.

Pot No.	Grams of dried spinach.	Group.	Materials applied other than nitrogen and the regular manures.
25	19.133	(G) Sulfate of Ammonia.	Potassium Sulfate.
26	19.028†		
27	19.344		
28	18.258		
Average	18.941		
29	18.585	(H) Sulfate of Ammonia.	Potassium Carbonate.
30	18.199		
35	17.235‡		
Average	18.006		

†One of the seven plants was eaten off, and this weight was obtained by dividing the weight of the remaining plants by six and multiplying by seven.

‡One plant was quite small.

It will be remembered that in the first year of the experiment less striking results were obtained than in the second season, when the cumulative effect of the manures made their action more apparent. In fact, the first season the results were not sufficiently striking to permit one to draw definite conclusions from the experiment. In view of the facts concerning both the first and second years' results in the first experiment, the indications afforded by the results in 1899 with the ordinary spinach are entitled to more significance than otherwise.

It will be observed that where nitrate of soda had been used (series A) the average yield per pot was 20.601 grams, and where sulfate of ammonia had been applied it was only 17.576 grams.[1] Concerning the cases where sulfate of ammonia was used, it will be seen that by the addition of a large amount of calcium carbonate the average yield was raised to 19.462 grams. The only other instance where the average yield was appreciably over 19 grams was where the large additional amount of sodium carbonate was employed.

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[1] Even eliminating the poor yield in pot No. 8, which it is believed was due to the unfavorable influence of the sulfate of ammonia rather than to other causes, the average would be only 18.45 grams.

Had the difference between the yield with nitrate of soda and sulfate of ammonia (groups A and B) been attributable solely to direct manurial action of the sodium in the nitrate of soda, or even to an indirect action in liberating potassium, it would have been expected that the use of the various sodium and potassium salts would have raised the yield essentially to that where nitrate of soda was employed. It will be remembered that the smaller application of sodium carbonate was not great enough to have, in one year, any material influence upon the chemical reaction of the soil, though it, like the amounts of the other sodium salts, was great enough to have exerted a most marked influence had it been needed as a direct manure.

It cannot well be claimed that the larger amount of sodium carbonate had been effective by virtue of liberating potassium compounds for the use of the plants; for had potassium not been present in sufficient quantity in the case when sulfate of ammonia was employed, the direct application of either the potassium sulfate or potassium carbonate should have raised the yield to that of the soil which received nitrate of soda. It is not surprising that the small amount of potassium carbonate, if not needed for manurial purposes, should have failed to exert a marked influence in decreasing the acidity of the soil, for the reasons in this case are the same as for the small application of sodium carbonate.

A Further Experiment With New Zealand Spinach.

July 24th of the same year, New Zealand spinach seed was planted to succeed the ordinary spinach as a second crop. No further manures were applied, though the soil in each pot was thoroughly mixed by emptying it out, breaking any lumps that were present, and replacing it in the pot from which it was taken. Below are given the weights of the crops from the various pots, after drying completely at 100° C:

Pot No.	Grams of dried New Zealand spinach.	Group.	Materials applied other than nitrogen and the regular manures.
1	47.333	(A) Nitrate of Soda.	None.
2	45.568		
3	46.149		
4	46.205		
Average	46.314		
5	37.970	(B) Sulfate of Ammonia.	None.
6	33.435		
7	38.995		
8	40.443		
Average	37.711		
9	36.839	(C) Sulfate of Ammonia.	Calcium Carbonate.
10	42.900		
11	36.215		
12	36.339		
Average	38.073		
13	36.420	(D) Sulfate of Ammonia.	Sodium Sulfate.
14	32.223		
15	39.679		
16	39.350		
Average	36.918		
17	40.740	(E) Sulfate of Ammonia.	Sodium Carbonate. (Small amount.)
18	40.103		
19	38.739		
20	37.755		
Average	39.334		
21	43.510	(F) Sulfate of Ammonia.	Sodium Carbonate. (Large amount.)
22	47.663		
23	39.409		
24	38.195		
Average	42.194		

Pot No.	Grams of dried New Zealand spinach.	Group.	Materials applied other than nitrogen and the regular manures.
25	30.146		
26	46.413	(G) Sulfate of Ammonia.	Potassium Sulfate.
27	36.559		
28	34.385		
Average	36.876		
29	37.020	(H) Sulfate of Ammonia.	Potassium Carbonate.
30	36.583		
35	38.649		
Average	37.417		

From the foregoing table it is seen that the average yield where nitrate of soda was used was 46.314 grams as compared with 37.711 grams where sulfate of ammonia was employed, thus agreeing with the result with the first crop. The average result where calcium carbonate was used in connection with the sulfate of ammonia was somewhat better than without the addition, though it was not equal in this instance to that where a small amount of sodium carbonate was added. In only one other instance was the yield increased in the case of the soil where sulfate of ammonia was used, excepting where the large amount of sodium carbonate was applied, in which instance it amounted to 42.194 grams. The fact that the large amount of sodium carbonate so very materially increased the yield over that obtained by the use of calcium carbonate is not surprising by virtue of the greater alkalinity and solubility of the sodium carbonate and consequently its more vigorous and quicker action. In fact, it proved superior to the calcium carbonate in the case of the first crop. It must be evident that if sodium had been needed as a direct manure, or if it exerted an action as an indirect manure in liberating potash, then the smaller applications of sodium salts should have exerted a marked effect or the potassium salts should have been distinctly efficacious.

While recognizing that the results secured in this last year's experiment cannot be considered as conclusive in themselves, yet they point in the same general direction as the first year's results in the former experiment. This gives ground for the belief that if the experiment had been continued for another year, as the first one was, most conclusive results would have been obtained; for in that case the results the first year were not striking, though those of the second year were most conclusive, fully bearing out the indications of the first year.

WAS THE GREATER EFFECTIVENESS OF NITROGEN IN NITRATE OF SODA AS COMPARED WITH THAT IN SULFATE OF AMMONIA DUE TO THE FACT THAT THE SODA HAD ACTED AS A MORE EFFICIENT CARRIER OF NITROGEN TO THE PLANT THAN THE BASES PRESENT IN THE OTHER CASE?

In discussing certain experiments with sugar beets,[1] Schneidewind and Müller call attention to the greater effectiveness of nitrate of soda, as compared with nitrate of potash, in the early stages of growth. They suggest that possibly the soda may assist the nitrogen in producing rapid leaf development, but seem to believe that the chief difference is due to the greater solubility and diffusibility of the nitrate of soda. They do not think that the soda plays a rôle like that attributed to potash in connection with the translocation of starch and sugar. A year later[2] Schneidewind found that nitrate of soda continued even to the end of the season to be more effective than nitrate of potash, and he again attributes the good results with nitrate of soda to the ease with which the readily soluble and diffusible salts of soda are able to carry to the plant essential ingredients such as sulfur, phosphorus, and nitrogen (in nitric acid). Lawes and Gilbert,[3] in discussing certain results secured in a study of the mixed herbage of permanent grass land, call attention to the service to plants which certain bases can perform as carriers of nitric acid, and express themselves as follows: "Evidence has been adduced pointing to the conclusion that lime and soda, and probably other bases—whatever other function they may perform—are at any rate to a great extent of importance as *carriers of nitrogen as nitric acid* into the plant."

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[1] Jour. f. Landw. 44 (1896), p. 10.

[2] Jour. f. Landw. 46 (1898), pp. 2–7.

[3] Phil. Trans. of the Royal Soc. of London. Series B., Vol. 192, pp. 186 and 190.

Recognizing that attention had been called to the importance of sodium as a carrier of nitric acid to the plant, it seemed desirable to ascertain whether or not such a function could be ascribed to it in the foregoing experiments; for if such were the case, it might be objected that the conclusions drawn were faulty and that the difference in the effectiveness of the nitrogen in nitrate of soda on the one hand, and in sulfate of ammonia on the other, was due to this circumstance rather than to the difference in the reaction of the soil. To this end the New Zealand spinach[1] which was the second crop in 1899, was analyzed in order to learn if the plants where nitrate of soda had been used were richer in nitrogen than those where sulfate of ammonia had been applied. Below are given the yields from the three series of pots particularly designed to throw light upon this point, together with the percentages of nitrogen in the dry matter of the spinach from each pot:

Special manuring.	No. of pot.	Weight of crop dried at 100° C. grams.	Per cent. of nitrogen in dry matter.
Nitrate of Soda....................	1	47.333	1.99
" "	2	45.568	2.00
" "	3	46.149	1.99
" "	4	46.205	2.09
	Average.....	46.314	2.02
Sulfate of Ammonia................	5	37.970	2.27
" "	6	33.435	2.06
" "	7	38.995	2.11
" "	8	40.443	1.83
	Average.......	37.711	2.07

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[1] See table, p. 261.

Special manuring.	No. of pot.	Weight of crop dried at 100° C. grams.	Per cent. of nitrogen in dry matter.
Sulfate of Ammonia and Lime.......	9	36.839	2.60
" " "	10	42.900	3.12
" " "	11	36.215	2.70
" " "	12	36.339	2.67
	Average..	38.073	2.77

From the foregoing figures it will be seen that the average per cent. of nitrogen in the dry matter of the crop was 0.05 less where nitrate of soda was used than where nitrogen had been applied in sulfate of ammonia. Furthermore, where sulfate of ammonia and lime were both employed and the average yield was somewhat better than where sulfate of ammonia was used without lime, the average per cent. of nitrogen in the dry matter of the crop was over 0.7 greater than where the nitrate of soda had been used. From this it is seen that the extra amount of lime apparently facilitated the nitrification of the sulfate of ammonia in a high degree, and that there was an abundance of nitrogen in readily assimilable combinations at the disposal of the plants.

The fact of the entry of the large amount of nitrogen into the plants showed their complete ability to satisfy themselves so far as this point was concerned; hence it would not appear that the advantage of nitrate of soda, so far as crop growth was concerned, could in this case have been attributable to its having acted as a ready carrier of nitrogen, since the carrying of nitrogen into the plants in the other series went on just as readily and in one case far more vigorously.

These results, therefore, still further lead to the conviction that a considerable part of the difference in the efficiency of nitrogen in sulfate of ammonia and in nitrate of soda is brought about by their effect upon the chemical reaction of the soil and the influence of this in turn upon plant growth.

SUMMARY.

The experiments were designed to throw light upon the question whether the frequent greater effectiveness of nitrate of soda as compared with sulfate of ammonia, when employed at such rates that each furnishes like amounts of nitrogen, is due to a direct manurial action of the sodium, as claimed by Wagner and Dorsch, or in part to other causes.

Other experiments at this Station with about two hundred varieties of plants have shown conclusively that plant growth is very greatly influenced by the chemical reaction of the soil, or by compounds formed as a result of the reaction, a fact which seems established beyond question. Many tests of soils, where both nitrate of soda and sulfate of ammonia have been used, have shown that they influence greatly the chemical reaction of the soil. The nitric acid of the nitrate of soda is taken up by plants leaving a basic residue, while on the other hand the ammonia of sulfate of ammonia is changed to nitric acid and utilized by plants, and sulfuric acid is left as a residual product.

Wagner and Dorsch, citing European experiments in support of their contention that nitrate of soda is frequently more efficacious than sulfate of ammonia by virtue of a direct manurial action of sodium, make no mention of a possible influence of the chemical reaction of the soil as affected by these salts. Indeed, they cite the Rothamstead results in support of their conclusions. It was pointed out, however, several years ago by one of us (H. J. W.) that the inefficiency of sulfate of ammonia at Rothamstead as compared with nitrate of soda was probably due to the resultant difference in the reaction of the soil which lime was shown to be capable of overcoming. In fact, recent experiments with lime at Rothamstead have shown that it corrects the condition, thus fully demonstrating the position taken at this Station, and furnishing further evidence in support of the conclusion from our own experiments. The results secured here are to the effect that the differences in the yields produced by nitrate of soda and sulfate of ammonia are not attributable, at least, more than to a limited extent, and then perhaps only with a few kinds of plants, to a direct manurial action of the sodium, but often chiefly to the difference in the chemical reaction of the soil which is brought about by the two salts.

The conclusion reached is further supported by the fact that the greater efficiency of nitrate of soda, as compared with sulfate of ammonia in our own experiments, was not apparently by virtue of the capacity of soda to act as a carrier of nitric acid to the plant.

BIOLOGICAL DIVISION.

POULTRY EXPERIMENTS.

13

REPORT OF THE BIOLOGICAL DIVISION.

COOPER CURTICE.

I take pleasure in reporting upon the work of the biological division for the year ended June 30, 1903, as follows:

The work has principally been in connection with the incubation and brooding of chickens.

In the incubation experiments, 8,677 eggs from various sources have been set in the incubators. Of these, 7,205, or 83 per cent., were fertile. Three thousand three hundred forty-eight, or 46 per cent., of the fertile eggs were hatched. This was 38.6 per cent. of the total number. The efficiency of hatching under various conditions ranged from 0 per cent. to 84 per cent. These experiments were planned in the direction of testing the efficiency of the machines and the influence of moisture and room temperature upon the hatch.

The incubation work done by the Short Course class in poultry keeping has been repeated, and gives material for comparisons with the preceding and future classes.

Data have also been collected in connection with the hatching of eggs under hens, in continuation of last year's work.

The chickens hatched have been brooded, but on account of the lack of coal and the character of the furnace which we had at that time these experiments were not all successful. The results have varied from 100 per cent. downward.

No turkey work has been done. While it was intended to secure a number of eggs from localities where it was believed that blackhead did not prevail, it was impossible to secure them in the quantities ordered, for one reason and another, and none were finally secured.

The division has advanced in material equipment during the year. Fourteen Old Homestead brooders, half large size and half junior, have been added. Heretofore, we had been brooding with a larger variety of brooders, and there was a question as to whether certain variations in the final results were due to the style of brooders or to other causes. In using brooders of the same pattern it was thought that the variations due to the style of brooder would be avoided. The Old Homestead was chosen because it was thought to answer our requirements for ascertaining the condition of brooding, and not especially because it was thought to be the best on the market.

During the spring much difficulty was experienced on account of the poor facilities for carrying larger chicks. The fences about the yards had been so poorly wired that not only were many of the chicks caught by cats and rats, but they would mix up promiscuously and prevent an exact record being kept as to their disappearance. Four of the houses have since been yarded with a seven-foot wire fence. The lower three feet of the fence is an inch mesh-wire net, of which six inches is buried in the ground. The upper four feet is a two-inch mesh. The posts are substantial, and the yards, including twice the area they formerly did, are much more practical for our purpose and present a far neater appearance. The fencing and repairs of the other five chicken houses belonging to the station, as contemplated, will place them in good condition for any future work.

In anticipation of experiments in raising turkeys, four yards, each a hundred foot square, have been laid out. The only ground available was adjoining the chicken yards in a plot covered by birches and undergrowth. This was cleared out, ditched, and fenced with a seven-foot wire netting. For brooding purposes, two portable houses, 7 x 9, were constructed and placed in two of the yards. The appropriation set aside for making culverts across the road and grading the ground adjacent to the incubator houses has greatly added to the appearance of the ground, and when the culverts are placed will add to the dryness of the incubator cellar and prevent the general wash of the soil which has heretofore occurred.

The biological laboratory has been repaired, and new furniture, including desk, closets, etc., has been placed therein. The considerable amount of bacteriological apparatus recently purchased for the division will place the laboratory in condition for bacteriological work. While not complete in its equipment, the purchase of small amounts of glass-ware, chemicals, and apparatus from time to time, will permit of any class of bacteriological work being done and will make the laboratory very efficient.

The details concerning incubation and brooding are so voluminous, if all are presented, that it would seem better to make certain selections bearing upon various questions and present them later in bulletins.

REPORT OF THE METEOROLOGIST.

NATHANIEL HELME.

Summary for 1902–1903.

Highest temperature	90.0°	July 9, August 4, 1902.
Lowest temperature	—12.0°	December 9, 1902.
Range for the year	102.0°	
Highest daily mean	77.5°	July 9, 1902.
Lowest daily mean	—2.0°	December 9, 1902.
Highest monthly mean	67.0°	July, 1902.
Lowest monthly mean	27.2°	December, 1902.
Mean temperature of the year.	48.3°	

Precipitation (rain and melted snow).

Greatest in any 24 consecutive hours.	2.50	inches,	April 15, 1903.
Largest total for one month	9.19	"	March, 1903.
Least total for one month	.70	"	May, 1903.
Total for the year	59.27	"	
Total snow-fall (unmelted)	45.00	"	

Prevailing Winds.

Northeast, September, November, 1902; east, May, June, 1903; southwest, July, 1902; west, August, October, December, 1902, January, February, March, April, 1903.

Weather.

Number of clear days in the year	138
Partly cloudy days	96
Cloudy days	131
Days with .01 inch or more of precipitation	103

SUMMARY BY MONTHS FOR 1902–1903.

MONTHS.	Highest temperature.	Lowest temperature.	Mean temperature.	Precipitation (rain and melted snow), inches.	Snow-fall (unmelted).	Clear days.	Partly cloudy days.	Cloudy days.	Days with .01 inch or more of precipitation.	Prevailing wind direction.
1902.										
July	90°	48°	67°	3.23	......	8	8	15	10	S.W.
August	90°	44°	66.8°	1.69	......	16	9	6	7	W.
September	83°	40°	61.9°	4.05	......	10	6	14	12	N.E.
October	75°	24°	52°	4.26	......	14	9	8	8	W.
November	70°	20°	44.8°	2.12	......	7	11	12	7	N.E.
December	54°	—12°	27.2°	8.03	26	10	11	10	10	W.
1903.										
January	52°	—2°	27.6°	5.50	7	10	10	11	8	W.
February	54°	—4°	29.7°	7.04	12	14	5	9	8	W.
March	68°	16°	42.6°	9.19	......	10	6	15	10	W.
April	83°	23°	46.1°	6.91	......	12	11	7	7	W.
May	90°	29°	57.4°	.70	......	20	5	6	5	E.
June	82°	42°	58.4°	6.55	......	7	5	18	11	E.
Total	......	....	......	59.27	45	138	96	131	103	......
Mean	......	......	48.3°	....	......	......	......	......	......	......

The principal characteristics of the weather for each month were as follows:

July weather was cloudy and cool. The mean temperature was below the average, and was but .6 of a degree more than the mean of the same month in 1891, which was the coolest July on our record. The rain-fall was below the average.

August mean temperature was 1.8 degrees below the average, and the rain-fall less than one-half the average, being the least for the month during the past 15 years. There was much cloudy weather in September, with frequent rains, but no severe storms. The temperature was very near, and the rain-fall slightly below, the average for the month.

October rain-falls were quite heavy, but the total was less than the average for the month. The temperature was above the average. The first frost of the fall formed on the 10th.

November mean temperature was the highest for the month since 1896. There were no severe storms during the month, and but a light flurry of snow. The precipitation was less than one-half of the average.

December precipitation was greatly above the average, and the snow-fall was very much in excess of that which generally falls in this month. The temperature was below the average, making it the coldest month of the winter. The minimum temperature of —12 degrees and the daily mean of —2 degrees, both on the 9th day of the month, were the lowest ever recorded during our fifteen years of observations.

January precipitation was above the average, and double that of January, 1902. There were no severe storms during the month, and the temperature was about the average.

February precipitation was mostly in the form of rain. There was but one snow-storm during the month, which gave several days of good sleighing. The mean temperature was 2 degrees above the average. The maximum temperature of March was the highest for that month in our 15 years' record. Another feature of the weather was the absence of snow during the entire month. The frost was practically out of the ground by the middle of the month and the season quite in advance of the ordinary for the time of year.

The first half of April was cold and wet, and the last half warm and dry and favorable for plowing and planting. The temperature and precipitation were each above the average for the month.

May was the dryest month of that name during our 15 years' record, the rain-fall being less than one-sixth of the average. At the end of the month all crops were suffering on account of lack of moisture. The mean temperature was above the average for the month.

June was notable for three days of dense smoke caused by extensive forest fires, for low temperatures, and heavy rain-fall. There were but three days when the maximum temperature was 75 degrees or above, while there were sixteen (16) when the minimum was 50 degrees or below. The rain-fall was more than double the average for the month during our 15 years' record, and the mean temperature far below the average for the month for the same time. On the morning of the 12th there was a strong gale which overturned several large trees and covered the ground with broken branches from a great many others.

The following tables give the highest, lowest, and mean temperature, precipitation, wind direction, and character of the day for every day of the year, and also a general summary for the years 1890 to June 30, 1903, inclusive:

WEATHER SUMMARY FOR JULY, 1902.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	71°	55°	63°	.19	Variable.	Fair.
2	81	49	65	....	N.W.	Clear.
3	66	56	61	.41	S.	Fair.
4	81	57	69	....	W.	Clear.
5	78	59	68.5	.67	Variable.	Cloudy.
6	72	56	64	....	N.E.	Fair.
7	72	48	60	....	S.E.	Fair.
8	75	61	68	.20	S.	Cloudy.
9	90	68	77.5	....	W.	Fair.
10	77	65	71	.04	W.	Cloudy.
11	80	62	66	....	W.	Clear.
12	79	52	65.5	....	S.W.	Clear.
13	84	54	69	....	S.W	Clear.
14	88	59	73.5	....	W.	Clear.
15	79	61	70	.69	S.W.	Fair.
16	76	56	66	....	W.	Clear.
17	72	48	60	....	S.W.	Cloudy.
18	82	64	73	.06	W.	Cloudy.
19	68	60	64	.31	E.	Cloudy.
20	66	58	62	.16	N.E.	Cloudy.
21	69	57	63	.50	E.	Cloudy.
22	79	60	69.5	....	N.	Fair.
23	75	59	67	....	N.E.	Cloudy.
24	70	59	64.5	....	N.E.	Cloudy.
25	66	58	62	....	N.E.	Cloudy.
26	68	56	62	....	N.E.	Cloudy.
27	68	54	61	....	S.	Cloudy.
28	86	64	75	....	S.W.	Cloudy.
29	85	64	74.5	....	Variable.	Cloudy.
30	78	64	71	....	N.E.	Fair.
31	83	58	70.5	....	Variable.	Clear.
Sum.......	2,364	1,788	2,076	3.23	....	....
Mean.....	76.3	57.7	67	....	....	....

Maximum temperature...............90°.
Minimum temperature...............48°.

Mean temperature...........67°.
Prevailing wind.......southwest.

WEATHER SUMMARY FOR AUGUST, 1902.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	79°	55°	67°	....	S.E.	Fair.
2	85	64	74.5	....	S.	Fair.
3	85	64	74.5	....	S.W.	Cloudy.
4	90	64	77	....	W.	Fair.
5	76	62	69	....	N.	Cloudy.
6	80	62	71	.02	S.	Cloudy.
7	77	57	67	trace.	W.	Clear.
8	80	54	67	.59	S.W.	Clear
9	80	53	66.5	....	S.W.	Clear.
10	79	57	68	....	N.E.	Fair.
11	81	63	72	.64	S.	Cloudy.
12	77	54	65	....	N.W.	Clear.
13	76	44	60	....	N.W.	Clear.
14	79	50	64.5	....	W.	Clear.
15	78	55	66.5	.16	S.W.	Fair
16	72	53	62.5	....	N.	Fair.
17	74	46	60	....	W.	Clear.
18	74	48	61	....	W.	Cloudy.
19	74	55	64.5	....	N.E.	Cloudy.
20	76	50	63	....	Variable.	Fair.
21	72	54	63	.20	Variable.	Fair.
22	78	57	67.5	....	W.	Fair
23	81	49	65	.02	N.W.	Clear.
24	74	50	62	....	S.E.	Clear.
25	67	54	60.5	.06	S.E.	Clear.
26	83	51	67	....	W.	Clear.
27	85	54	69.5	trace.	W.	Clear.
28	78	58	68	....	N.E.	Fair.
29	77	52	64.5	....	Variable.	Clear.
30	78	55	66.5	....	S.W.	Clear.
31	83	59	71	....	S.W.	Clear.
Sum.........	2,441	1,703	2,072	1.69	....	....
Mean.......	78.7	54.9	66.8	....	....	....

Maximum temperature...............90°. Mean temperature.........66.8°.
Minimum temperature...............44°. Prevailing wind.............west.

WEATHER SUMMARY FOR SEPTEMBER, 1902.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	83°	63°	73°	....	S W.	Clear.
2	82	60	71	.03	S.W.	Fair.
3	77	50	63.5	....	S.E.	Clear.
4	74	57	65.5	.62	S.W.	Cloudy.
5	70	48	59	....	N.W.	Clear.
6	67	44	55.5	....	N.E.	Fair.
7	72	58	65	.06	S.E.	Fair.
8	79	55	67	....	Variable.	Clear.
9	76	55	65.5	1.00	S.E.	Cloudy.
10	70	52	61	....	N.W.	Fair.
11	75	45	60	....	Variable.	Clear.
12	73	50	61.5	....	S.	Clear.
13	68	55	61.5	.50	S.E.	Cloudy.
14	70	46	58	....	N.W.	Clear.
15	69	40	54.5	....	N.E.	Clear.
16	72	43	57.5	....	N.	Clear.
17	70	46	58	....	N.E.	Fair.
18	62	53	57.5	.54	N.E.	Cloudy.
19	70	58	64	.28	N.E.	Cloudy.
20	72	58	65	....	N.E.	Cloudy.
21	72	56	64	....	N.E.	Cloudy.
22	65	55	60	.04	N.E.	Cloudy.
23	77	53	65	....	Variable.	Clear.
24	75	53	64	....	N.	Cloudy.
25	57	45	51	trace.	N.E.	Cloudy.
26	62	48	55	.29	N.E.	Cloudy.
27	70	58	64	.45	E.	Cloudy.
28	70	60	65	.22	E.	Cloudy.
29	73	55	64	....	W.	Fair.
30	68	56	62	.02	N.E.	Cloudy.
Sum........	2,140	1,575	1857.5	4.05	....	....
Mean.......	71.3	52.5	61.9	....	....	....

Maximum temperature................83°. Mean temperature............61.9°.
Minimum temperature................40°. Prevailing wind........northeast.

WEATHER SUMMARY FOR OCTOBER, 1902.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	63°	57°	60°	.45	N.E.	Cloudy.
2	75	56	65.5	....	E.	Fair.
3	72	56	64	....	Variable.	Cloudy.
4	66	51	58.5	....	N.E.	Cloudy.
5	62	53	57.5	.62	E.	Cloudy.
6	72	54	63	.57	S.W.	Fair.
7	69	44	56.5	....	S.W.	Clear.
8	63	43	53	....	W.	Clear.
9	71	43	57	....	S.W.	Clear.
10	59	31	45	....	W.	Clear.
11	63	35	49	.09	Variable.	Cloudy.
12	57	50	53.5	.90	N.E.	Fair.
13	68	46	57	....	S.	Fair.
14	67	46	56.5	.19	W.	Fair.
15	59	33	46	....	W.	Clear.
16	66	40	53	....	W.	Clear.
17	52	34	43	....	N.E.	Fair.
18	60	44	52	trace.	Variable.	Cloudy.
19	70	58	64	....	S.W.	Fair.
20	65	47	56	....	W.	Clear.
21	53	31	42	....	W.	Clear.
22	55	25	40	....	W.	Clear.
23	55	40	47.5	.06	Variable.	Fair.
24	58	33	45.5	....	Variable.	Cloudy
25	67	39	53	....	W	Clear
26	49	29	39	....	N.E.	Clear.
27	65	42	53.5	....	S.	Cloudy.
28	64	45	54.5	1.38	W.	Fair.
29	47	33	40	....	W.	Clear.
30	52	24	38	....	W.	Clear.
31	60	41	50.5	....	W.	Clear.
Sum........	1,924	1,303	1613.5	4.26	....	....
Mean.......	62	42	52	....	....	....

Maximum temperature................75°.	Mean temperature..............52°.
Minimum temperature................24°.	Prevailing wind.............west.

WEATHER SUMMARY FOR NOVEMBER, 1902.

	TEMPERATURE.			PRECIPITATION.	PRECIPITATION.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	51°	29°	40°	....	N E.	Clear.
2	59	33	46	....	S.W.	Clear.
3	61	34	47.5	....	S.	Clear
4	62	42	52	....	Variable.	Clear.
5	57	35	46	....	S.	Fair.
6	60	44	52	.13	S.	Cloudy.
7	58	38	48	....	Variable.	Fair.
8	48	29	38.5	....	N.E.	Cloudy.
9	49	33	41	....	N.E.	Cloudy.
10	70	32	51	....	N.W.	Fair.
11	53	28	40.5	....	Variable.	Fair.
12	58	38	48	.05	S.	Cloudy.
13	55	37	46	....	N.E.	Cloudy.
14	60	36	48	....	S.W.	Fair.
15	58	47	57.5	....	S.W.	Fair.
16	60	45	52.5	....	Variable.	Fair.
17	50	37	43.5	....	N.E.	Cloudy.
18	49	37	43	....	N.E.	Cloudy.
19	52	40	46	....	N.E.	Fair.
20	57	34	45.5	....	S.	Clear.
21	60	36	48	....	S.	Fair.
22	62	39	50.5	.30	S.W.	Fair.
23	50	31	40.5	....	N.W.	Clear.
24	56	27	41.5	.16	S.	Cloudy.
25	48	42	45	....	Variable.	Cloudy.
26	45	33	39	.94	N.E.	Cloudy.
27	48	32	40	.08	N.E.	Cloudy.
28	38	25	31.5	....	W.	Fair.
29	46	20	33	....	Variable.	Clear.
30	53	35	44	.46	S.W.	Cloudy.
Sum.........	1,643	1,048	1345.5	2.12	....	....
Mean.......	54.8	34.9	44.8	....	....	....

Maximum temperature................70°.
Minimum temperature................20°.

Mean temperature..........44.8°.
Prevailing wind........northeast.

WEATHER SUMMARY FOR DECEMBER, 1902.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	43°	27°	35°	....	N.W.	Clear.
2	50	25	37.5	....	W.	Fair.
3	47	39	43	.52	W.	Fair.
4	47	32	39.5	....	W.	Fair.
5	35	16	25.5	.88	N.W.	Fair.
6	22	7	14.5	....	W.	Clear.
7	37	9	23	.20	Variable.	Fair.
8	31	8	19.5	....	W.	Clear.
9	8	—12	—2	....	W.	Clear.
10	37	—6	15.5	....	S.W.	Cloudy.
11	37	20	28.5	.32	N.E.	Cloudy.
12	23	15	19	....	N.E.	Cloudy.
13	29	12	20.5	.82	N.E.	Cloudy.
14	22	9	15.5	.20	N.	Fair.
15	32	7	19.5	....	Variable.	Cloudy.
16	50	28	39	1.60	S.E.	Cloudy.
17	52	30	41	....	W.	Clear.
18	40	25	32.5	....	W.	Fair.
19	43	23	33	....	W.	Fair.
20	42	28	35	....	Variable.	Fair.
21	49	29	39	1.94	N.E.	Cloudy.
22	54	38	46	....	W.	Cloudy.
23	41	17	29	....	N.W.	Clear.
24	29	10	19.5	....	N.E.	Fair.
25	31	16	23.5	1.10	N.E.	Cloudy.
26	32	20	26	....	W.	Cloudy.
27	30	13	21.5	trace.	W.	Clear.
28	25	5	15	....	W.	Clear.
29	40	12	26	.45	S.	Fair.
30	43	25	34	....	W.	Clear.
31	40	17	28.5	....	W.	Clear.
Sum........	51,141	544	842.5	8.03	....	....
Mean.......	36.8	17.6	27.2	....	....	....

Maximum temperature................54°.	Mean temperature.........27.2°.
Minimum temperature............. —12°.	Prevailing wind..............west.

WEATHER SUMMARY FOR JANUARY, 1903.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	45°	20°	32.5°	....	W.	Clear.
2	52	25	38.5	....	S.	Fair.
3	43	34	38.5	1.12	Variable.	Cloudy.
4	39	31	35	trace.	N.W.	Cloudy.
5	40	29	34.5	....	W.	Cloudy.
6	37	25	31	.36	Variable.	Cloudy.
7	34	13	23.5	.15	S.	Fair.
8	38	18	28	....	W.	Fair.
9	20	8	14	....	W.	Clear.
10	28	9	18.5	....	W.	Clear.
11	47	10	28.5	1.30	Variable.	Cloudy.
12	49	15	32	....	W.	Clear.
13	25	8	16.5	....	W.	Clear.
14	25	9	17	....	W.	Fair.
15	37	20	28.5	....	W.	Cloudy.
16	40	30	35	....	W.	Fair.
17	44	29	36.5	....	W.	Fair.
18	33	7	20	....	W.	Clear.
19	20	—2	9	....	W.	Clear.
20	33	3	18	....	Variable.	Fair.
21	49	31	40	1.73	S.E.	Fair.
22	40	28	34	....	W.	Cloudy.
23	38	16	27	....	W.	Clear.
24	19	4	11.5	....	N.E.	Fair.
25	23	13	18	.40	N.E.	Cloudy.
26	30	15	22.5	....	N.	Clear.
27	42	16	29	....	S.W.	Cloudy.
28	46	34	40	.12	S.W.	Fair.
29	40	29	34.5	....	N.E.	Cloudy.
30	46	28	37	.32	S.W.	Cloudy.
31	33	21	27	....	W.	Clear.
Sum.......	1,135	57.6	855.5	5.50	....	....
Mean......	36.6	18.6	27.6	....	....	....

Maximum temperature................52°. **Mean temperature**...........27.6°.
Minimum temperature.............. —2°. **Prevailing wind**............west.

WEATHER SUMMARY FOR FEBRUARY 1903.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	40°	22°	31°	.02	S.	Cloudy.
2	42	34	38	.30	S.	Cloudy.
3	49	32	40.5	....	W.	Clear.
4	47	32	39.5	1.60	E.	Cloudy.
5	45	19	32	....	W.	Clear.
6	38	18	28	....	W.	Clear.
7	38	22	30	....	W.	Clear.
8	45	19	32	.68	Variable.	Cloudy.
9	35	25	30	....	W.	Clear.
10	43	24	33.5	....	W.	Clear.
11	44	28	36	1.40	S.E.	Fair.
12	49	37	43	....	W.	Clear.
13	54	31	42.5	....	W.	Fair.
14	38	24	31	....	W.	Fair.
15	28	21	24.5	trace.	N.	Cloudy.
16	32	26	29	.79	N.E.	Cloudy.
17	26	4	15	1.00	N.W.	Fair.
18	14	—4	5	....	W.	Fair.
19	10	—4	3	....	W.	Clear.
20	27	—1	13	....	W.	Clear.
21	37	8	22.5	....	S.W.	Fair.
22	32	19	25.5	....	W.	Clear.
23	40	13	26.5	....	S.W.	Clear.
24	45	26	35.5	....	W.	Cloudy.
25	37	13	25	....	W.	Clear.
26	47	19	33	....	W.	Clear.
27	52	27	39.5	....	S.W.	Cloudy.
28	54	39	46.5	1.25	S.	Cloudy.
Sum......	1,088	573	835.5	7.04	....	....
Mean......	38.9	205	29.7 ..	....	....	....

Maximum temperature...............54°.
Minimum temperature............. —4°.

Mean temperature...........29.7°.
Prevailing wind............west.

WEATHER SUMMARY FOR MARCH, 1903.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	48°	24°	36°	....	W.	Clear.
2	40	16	28	....	W.	Clear.
3	37	25	31	....	E.	Cloudy.
4	52	29	40.5	....	S.W.	Clear.
5	43	32	37.5	.04	S.	Cloudy.
6	52	32	42	....	N.W.	Clear.
7	43	26	31.5	....	E.	Fair.
8	50	37	43.5	1.25	S.	Cloudy.
9	48	37	42.5	1.79	N.	Cloudy.
10	47	34	40.5	....	N.	Cloudy.
11	48	38	43	.68	S.W.	Cloudy.
12	56	34	45	....	Variable.	Clear.
13	62	32	47	....	S.	Clear.
14	68	32	50	....	S.W.	Clear.
15	50	35	42.5	....	N.E.	Fair.
16	40	34	37	....	N.E.	Cloudy.
17	55	35	45	....	S.W.	Fair.
18	53	37	45	....	Variable.	Clear.
19	58	36	47	....	S.W.	Cloudy.
20	62	40	51	....	S.W.	Cloudy.
21	55	42	48.5	.68	S.	Cloudy.
22	53	42	47.5	1.38	N.E.	Cloudy.
23	56	40	48	1.51	S.	Cloudy.
24	55	46	50.5	....	S.W.	Cloudy.
25	53	37	45	....	W.	Fair.
26	55	29	42	....	W.	Clear.
27	63	36	49.5	....	S.W.	Fair.
28	53	36	44.5	.03	N.E.	Cloudy.
29	45	27	36	....	N.E.	Clear.
30	42	27	34.5	.51	N.E.	Cloudy.
31	53	38	45.5	1.32	N.	Fair.
Sum......	1,595	1,045	1,320	9.19	....	....
Mean......	51.5	33.7	42.6	....	....	....

Maximum temperature................68°.
Minimum temperature................16°.
Mean temperature..........42.6°.
Prevailing wind............west.

WEATHER SUMMARY FOR APRIL, 1903.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	57°	37°	47°	....	N.W.	Clear.
2	51	31	41	....	Variable.	Fair.
3	55	45	50	.08	S.	Cloudy.
4	55	27	41	.38	S.W.	Cloudy.
5	40	24	32	....	N.W.	Clear.
6	42	23	32.5	....	S.	Fair.
7	48	37	42.5	1.63	S.	Cloudy.
8	53	45	49	2.15	S.	Cloudy.
9	62	41	51.5	.15	S.W.	Fair.
10	58	40	49	....	N.W.	Clear.
11	51	39	45	....	W.	Clear.
12	59	35	47	....	W.	Fair.
13	54	34	44	....	N.E.	Fair.
14	47	36	41.5	....	N.E.	Cloudy.
15	40	35	37.5	2.50	N.E.	Cloudy.
16	42	33	37.5	....	N.E.	Cloudy.
17	47	35	41	....	N.	Fair.
18	60	29	44.5	....	W.	Clear.
19	57	29	43	....	W.	Clear.
20	62	33	47.5	....	S.W.	Clear.
21	60	35	47.5	....	Variable.	Clear.
22	55	33	44	....	S.	Fair.
23	56	36	46	....	S.	Fair.
24	59	40	49.5	.02	Variable.	Fair.
25	59	39	49	....	N.W.	Fair.
26	58	37	47.5	....	E.	Fair.
27	60	38	49	....	N.	Clear.
28	72	39	55.5	....	N.W.	Clear.
29	83	46	64.5	....	S.W.	Clear.
30	78	55	66.5	....	S.W.	Clear.
Sum......	1,680	1,086	1,383	6.91	....	....
Mean......	56	36.2	46.1	....	....	....

Maximum temperature................83°.
Minimum temperature................23°.
Mean temperature.........46.1°.
Prevailing wind............west.

WEATHER SUMMARY FOR MAY, 1903.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	55°	39°	47°	....	N.W.	Clear.
2	49	29	39	....	N.E.	Clear.
3	52	33	42.5	....	N.E.	Cloudy.
4	54	44	49	.07	N.	Cloudy.
5	59	44	51.5	....	N.E.	Cloudy.
6	59	44	51.5	....	N.E.	Cloudy.
7	61	40	50.5	.10	S.W.	Clear.
8	71	39	55	.01	Variable.	Clear.
9	73	47	60	....	N.E.	Clear.
10	63	42	52.5	....	S.E.	Clear.
11	66	39	52.5	....	E.	Clear.
12	66	41	53.5	....	Variable.	Clear.
13	69	43	56	....	S.	Clear.
14	77	49	63	....	S.	Clear.
15	74	52	63	trace.	Variable.	Fair.
16	67	47	57	....	S.E.	Fair.
17	75	41	58	....	W.	Clear.
18	85	53	69	....	S.W.	Clear.
19	87	59	73	trace.	S.W.	Clear.
20	90	64	77	.02	W.	Clear.
21	84	60	72	....	W.	Clear.
22	85	58	71.5	....	W.	Fair.
23	74	49	61.5	....	N.W.	Fair.
24	57	40	48.5	....	Variable.	Cloudy.
25	65	41	53	....	E.	Clear.
26	63	40	51.5	....	S.E.	Clear.
27	72	40	56	....	S.	Fair.
28	70	58	64	....	S.	Cloudy.
29	81	57	69	....	W.	Clear.
30	64	48	56	.50	N.E.	Fair.
31	65	45	55	....	N.E.	Clear.
Sum......	2,132	1,425	1,778.5	.70	....	....
Mean......	61.8	46	57.4	....	....	....

Maximum temperature................90°. **Mean temperature.........57.4°.**
Minimum temperature................29°. **Prevailing wind............east.**

WEATHER SUMMARY FOR JUNE, 1903.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	70°	42°	56°	....	Variable.	Clear.
2	69	47	58	....	Variable.	Clear.
3	82	46	64	....	W.	Clear.
4	69	49	59	....	N.E.	Smoky.
5	65	43	54	....	E.	Smoky.
6	68	50	59	....	W.	Clear.
7	68	51	59.5	.41	S.E.	Cloudy.
8	70	59	64.5	.86	S.E.	Cloudy.
9	75	59	67	....	S.	Cloudy.
10	69	57	63	....	S.E.	Cloudy.
11	72	59	65.5	.39	S.E.	Cloudy.
12	65	57	61	1.77	E.	Cloudy.
13	70	54	62	.45	S.E.	Fair.
14	67	51	59	....	S.	Fair.
15	59	49	54	1.07	N.	Cloudy.
16	56	46	51	....	N.	Cloudy.
17	67	44	55.5	....	Variable.	Fair.
18	61	50	55.5	....	E.	Cloudy.
19	60	50	55	....	E.	Cloudy.
20	63	50	56.5	.05	E.	Cloudy.
21	59	52	55.5	1.10	E.	Cloudy.
22	56	48	52	....	N.E.	Cloudy.
23	55	43	49	.20	E.	Cloudy.
24	54	47	50.5	.12	N.E.	Cloudy.
25	63	47	55	....	Variable.	Cloudy.
26	72	53	62.5	....	S.W.	Fair.
27	79	53	66	....	S.W.	Clear.
28	70	53	61.5	....	S.W.	Fair.
29	67	53	60	.13	N.E.	Cloudy.
30	71	53	62	....	S.W.	Cloudy.
Sum.........	1,991	1,515	1,753	6.55	....	....
Mean.......	66.4	50.5	58.4	....	....	....

Maximum temperature...............82°.
Minimum temperature...............42°.

Mean temperature.........58.40
Prevailing wind............east.

SUMMARY, 1890 TO JUNE 30, 1903, INCLUSIVE.

	Maximum temperature.	Minimum temperature.	Mean temperature.	Number of clear days.	Partly cloudy days.	Cloudy days.	Days with .01 inch or more of precipitation.	Total precipitation (inches).
1890	91°	3°	48.3°	99	143	123	120	59.25
1891	94	5	49.4	116	154	95	83	49.88
1892	92	—1	47.8	147	116	103	89	42.58
1893	92	—6	46.5	126	130	109	131	57.33
1894	93	—9	48.6	110	130	125	114	48.19
1895	95	—7	48.2	128	114	123	108	49.28
1896	93	—11	47.7	131	112	123	109	49.87
1897	90	1	48.3	129	126	110	128	54.25
1898	95	—4	48.8	110	114	141	131	72.21
1899, January 1 to July 1	95	—10	42.1	77	44	60	59	26.79
July 1, 1899 to July 1, 1900	90	—5	48.3	141	113	111	102	51.67
July 1, 1900 to July 1, 1901	97	—9	48.4	134	97	134	114	48.47
July 1, 1901 to July 1, 1902	93	—1	48	138	116	111	109	53.14
July 1, 1902 to July 1, 1903	90	—12	48.3	138	96	131	103	59.27

Average temperature 13½ years..............................49.5°.
Average precipitation, 13½ years.......................53.49 inches.

REPORT OF THE TREASURER.

THE RHODE ISLAND STATE AGRICULTURAL EXPERIMENT STATION, *in account with the* UNITED STATES APPROPRIATION.

1903.	DR.		
	To receipts from the treasurer of the United States as per appropriation for fiscal year ended June 30, 1903, as per act of Congress approved March 2, 1887		$15,000 00
1903.	CR.		
	By Salaries	$7,794 97	
	Labor	2,334 53	
	Postage and stationery	218 96	
	Freight and express	142 35	
	Heat, light, and water	785 11	
	Chemical supplies	53 72	
	Seeds, plants, and sundry supplies	834 12	
	Fertilizers	229 17	
	Feeding stuffs	570 92	
	Library	274 78	
	Tools, implements, and machinery	306 43	
	Furniture and fixtures	628 40	
	Scientific apparatus	342 23	
	Traveling expenses	203 80	
	Contingent expenses	16 00	
	Building and repairs	264 51	
			$15,000 00

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the Rhode Island State Agricultural Experiment Station for the fiscal year ended June 30, 1903; that we have found the same well kept and classified as above, and that the receipts for the year from the treasurer of the United States are shown to have been $15,000, and the corresponding disbursements $15,000, for all of which proper vouchers are on file, and have been by us examined and found correct, thus leaving no balance.

And we further certify that the expenditures have been solely for the purposes set forth in the act of Congress approved March 2, 1887.

CHARLES DEAN KIMBALL,
C. H. COGGESHALL,
Auditors.

MELVILLE BULL, *Treasurer, in account with the* RHODE ISLAND STATE AGRICULTURAL EXPERIMENT STATION.

1903.	DR.
To balance from last year	$1,145 79
Station receipts	1,227 92
Interest	105 71
	$2,479 42

1903.	CR.
By publications	$17 38
Heat, light, and water	154 94
Furniture and fixtures	131 07
Traveling	13 81
Contingent expenses	4 50
Balance	2,157 72
	$2,479 42

This certifies that we, the undersigned, auditing committee of the Board of Managers of the Rhode Island College of Agriculture and Mechanic Arts, have examined the accounts of Melville Bull, treasurer of the Rhode Island State Agricultural Experiment Station, and find the same correct.

The total receipts were $2,479.42, and the total expenditures were $321.70, thus leaving a balance to new account of $2,157.72.

CHARLES DEAN KIMBALL,
C. H. COGGESHALL,
Auditors.

DONATIONS, 1902-1903.

American Philosphical Society.—Proceedings of the Society.

Bulletins of the New York State Museum.

Publications of the Florida Department of Agriculture.

Publications of the Maine State Board of Agriculture.

Publications of the Massachusetts State Board of Agriculture.

Publications of the North Carolina State Board of Agriculture.

Publications of the Ohio State Board of Agriculture.

Publications of the Pennsylvania Department of Agriculture.

Publications of the Rhode Island State Board of Agriculture.

Publications of the Virginia Department of Agriculture.

Toogood's Treatise on Pastures and Pasture Plants.

University of Minnesota.—Current numbers of Minnesota Botanical Studies.

German Kali Works.—Miscellaneous publications.

Chilian Nitrate Works.—Miscellaneous publications, and nitrate of soda.

DONATIONS FROM FOREIGN COUNTRIES.

Botanical Department, Jamaica.—Bulletins of the Botanical Department and Reports of Public Gardens and Plantations, by Wm. Fawcett, B. S., F. L. S.

Department of Agriculture, Victoria.—Current publications.

Department of Agriculture of Western Australia.—Journal.

Department of Agriculture, Queensland.—Annual Report, 1902-1903.

Department of Agriculture, New Zealand.—Annual Report.

Journal Khedivial Agricultural Society and School of Agriculture, Egypt.

Miscellaneous publications of the Natal Department of Agriculture and Mines.

Publications of the Department of Agriculture, University College, North Wales.

Report of the Director of the Sugar Experiment Station, Queensland.

Sec. de Fomento, Mexico.—Boletin de la Comisión de Parasitología Agricola.

Station Viticole de Villefranche (Rhone).—La Grele et la Defence des Recoltes.

Sec. da Agr. Estado de Sao Paulo.—Boletim da Agricultura, 1902-1903.

EXCHANGES.

Aboriculture, Connersville, Ind.
A Few Hens, Boston, Mass.
Agricultural Advertising, Pittsburg, Pa.
Agricultural Epitomist, Indianapolis, Ind.
Agricultural Experiments, Minneapolis, Minn.
Agricultural Gazette of New South Wales, Australia.
Agricultural Ledger, Calcutta, India.
American Agriculturist, New York, N. Y.
American Cultivator, Boston, Mass.
American Fancier, Johnstown, N. Y.
American Hay, Flour, and Feed Journal, New York, N. Y.
American Horse Breeder, Boston and New York.
American Pigeon Keeper, Peoria, Ill.
American Poultry Advocate, Syracuse, N. Y.
American Poultry Journal, Chicago, Ill.
American Sheep Breeder and Wool Grower, Chicago, Ill.
American Stock Keeper, Boston, Mass.
Baltimore Weekly Sun, Baltimore, Md.
Beet Sugar Gazette, Chicago, Ill.
Belgian Hare Advocate, Poneto, Ind.
Breeders' Gazette, Chicago, Ill.
Colman's Rural World, St. Louis, Mo.
Connecticut Farmer, Hartford, Conn.
Egg Reporter, St. Louis, Mo.
Elgin Dairy Report, Elgin, Ill.
Evening Telegram, Providence, R. I.
Fanciers' Review, Edinburgh, Scotland.

Fanciers' Review, Chatham, N. Y.
Farm and Home, Springfield, Mass.
Farm, Field, and Fireside, Chicago, Ill.
Farm Home, Springfield, Ill.
Farm Journal, Philadelphia, Pa.
Farm Poultry, Boston, Mass.
Farm, Stock and Home, Minneapolis, Minn.
Farmers' Advocate, London, Ontario.
Farmers' Guide, Huntington, Ind.
Farmers' Review, Chicago, Ill.
Farmers' Sentinel, Milwaukee, Wis.
Farmers' Tribune, Des Moines, Iowa.
Farmers' Voice, Chicago, Ill.
Feather, Washington, D. C.
Feathered World, London, England.
Flour and Feed, Waukegan, Ill.
Green's Fruit Grower, Rochester, N. Y.
Hoard's Dairyman, Fort Atkinson, Wis.
Holstein-Friesian Register, Brattleboro, Vt.
Home and Flowers, Springfield, Ohio.
Homestead, Des Moines, Iowa.
Hope Valley Free Press, Hope Valley, R. I.
Hospodarske Listy, Chicago, Ill.
Indiana Farmer, Indianapolis, Ind.
Inland Poultry Journal, Indianapolis, Ind.
Journal Royal Hort. Society, London, Eng.
Kansas Farmer, Topeka, Kan.
L'Aviculture Belge, Liege.
L'Ingenuier Agricole, De Gembloux, Belgium.
Maryland Agricultural Quarterly, College Park, Md.
Massachusetts Ploughman, Boston, Mass.
National Farmer and Stock Grower, National Stock Yards, Ill.
National Stockman and Farmer, Pittsburg, Pa.
Nebraska Farmer, Omaha, Neb.

New England Farmer, Boston, Mass.
New England Homestead, Springfield, Mass.
New Farm, Preston, Md.
New Hampshire Farmer and Weekly Union, Manchester, N. H.
New York Farmer, Fort Jervis, N. Y.
New York Tribune and Fármer, New York, N. Y.
Northwest Horticulturist, Tacoma and Seattle, Washington.
Ohio Farmer, Cleveland, Ohio.
Ohio Poultry Journal, Dayton, Ohio.
Oregon Agriculturist, Portland, Oregon.
Orff's Farm and Poultry Review, St. Louis, Mo.
Our Grange Homes, Boston, Mass.
Pet Stock Tribune, Los Angeles, Cal.
Poultry Gazette, Topeka, Kan.
Poultry Herald, St. Paul, Minn.
Poultry Item, Fricks, Pa.
Poultry Keeper, Parkesburg, Pa.
Poultry Standard, Stamford, Conn.
Poultry Success, Des Moines, Iowa.
Poultry Topics, Lincoln, Nebraska.
Practical Farmer, Philadelphia, Pa.
Practical Fruit Grower, Springfield, Mo.
Practical Poultryman, Whitney's Point, N. Y.
Providence News, Providence, R. I.
Queensland Agricultural Journal, Australia.
Reliable Poultry Journal, Quincy, Ill.
Republic, The, St. Louis, Mo.
Rock Products, Louisville, Ky.
Rural New Yorker, New York, N. Y.
Rural World, London, England.
Skandinavisk Farmer Journal, Minneapolis, Minn.
Southern Fancier, Atlanta, Ga.
Southern Planter, Richmond, Va.
Sugar Beet, Philadelphia, Pa.

Texas Farmer, Dallas, Texas.
Trade, The, Baltimore, Md.
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Wisconsin Agriculturist, Racine, Wis.
Yearbook and Current Publications der Deutschen Landwirtschafts-Gessellschaft.

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* Vols. 1-3 in one cover. Beginning with Vol. 4 a title page and index for each volume is to be found at the end of the annual report for each year. The year covered by a volume formerly was the calendar year, but now it extends from July 1 to June 30. Each volume, beginning with volume 4, is paged separately. The Bulletins of a given year precede the Report, and the latter is paged in continuation of the last Bulletin belonging in the volume.

BULLETINS

AND

ANNUAL REPORT

OF THE

RHODE ISLAND AGRICULTURAL EXPERIMENT STATION,

FOR THE

YEAR ENDING JUNE 30,

1903.

PROVIDENCE:
E. L. FREEMAN & SONS, STATE PRINTERS.
1904

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RHODE ISLAND AGRICULTURAL EXPERIMENT STATION,

FOR THE

YEAR ENDING JUNE 30, 1903.

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State of Rhode Island and Providence Plantations.

SEVENTEENTH ANNUAL REPORT

OF THE

RHODE ISLAND,

AGRICULTURAL EXPERIMENT STATION, Kingston

1903-1904.

PART II.

OF THE

SEVENTEENTH ANNUAL REPORT

OF THE

CORPORATION, BOARD OF MANAGERS

OF THE

Rhode Island College of Agriculture and Mechanic Arts,

MADE TO THE

GENERAL ASSEMBLY AT ITS JANUARY SESSION, 1905.

[PARTS I. AND III. OF THIS REPORT — REPORT OF PRESIDENT AND BOARD OF MANAGERS AND COLLEGE CATALOGUE — ARE PRINTED UNDER SEPARATE COVERS.]

PROVIDENCE, R. I.:
E. L. FREEMAN & SONS, PRINTERS TO THE STATE.
1905.

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JAMES W. KELLOGG, B. Sc.	First Assistant, Chemistry.

OTHER MEMBERS OF THE STATION STAFF

*	Second Assistant, Chemistry.
NATHANIEL HELME	Meteorology.
BEULAH A. HOITT	Stenographer and Accountant.
MARTHA VICKERY	Stenographer and Librarian.

---

* H. M. Soper, B. Sc., appointed to begin his duties July 1, 1904, *vice* A. G. Lauder, B. Sc., resigned.

The publications of the station will be mailed free on request to any one in Rhode Island interested in agriculture. The station desires the co-operation of the farmers of the state in the work of investigation, and any facts of special interest concerning animal or vegetable growth or disease are solicited. Visitors are always welcome. Railroad station, telegraph, express, and post-office—Kingston, Rhode Island. Long distance telephone, 46-6—Narragansett Pier exchange.

LETTER OF TRANSMITTAL.

To His Excellency Lucius F. C. Garvin, Governor, and the Honorable the General Assembly of the State of Rhode Island, at its January Session, 1905.

KINGSTON, R. I., June 30, 1904.

I have the pleasure to present herewith, in compliance with the statute of the State and the Congressional act of March 2, 1887, the Report of the Director of the Rhode Island Agricultural Experiment Station for the year ending June 30, 1904.

Respectfully submitted,

For the Board of Managers,

CHARLES DEAN KIMBALL,

President.

AGRICULTURAL EXPERIMENT STATION

OF THE

RHODE ISLAND COLLEGE OF AGRICULTURE AND MECHANIC ARTS.

KINGSTON, R. I., June 30, 1904.

HON. CHARLES DEAN KIMBALL,
President, Board of Managers.

SIR:—I have the honor to transmit herewith the Seventeenth Annual Report of the Rhode Island Agricultural Experiment Station for the year ending June 30, 1904.

Respectfully yours,

H. J. WHEELER,
Director.

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DIRECTOR'S REPORT.

REPORT OF THE DIRECTOR.

KINGSTON, R. I., Aug. 3, 1904.

To Honorable Charles Dean Kimball, President of the Board of Managers of the Rhode Island College of Agriculture and Mechanic Arts.

SIR:—It gives me pleasure to report in detail upon the work of the Agricultural Experiment Station for the year ending June 30, 1904.

HORTICULTURAL DIVISION.

In the horticultural division the work has been continued under the charge of Professor Fred. W. Card, assisted by Mr. A. E. Stene. This division has answered numerous inquiries during the year respecting the best means of controlling and combating the various insect pests and fungous diseases which attack the plants, shrubs, and trees of Rhode Island. Many inquiries in relation to various phases of horticultural work have also been answered during the year.

In experimental lines, the investigation of the influence of the cion upon the productiveness and the year of chief fruitfulness of apple trees has been continued.

The study of the apple maggot has likewise been pursued, in continuation of the work of former years. This is one of the serious pests with which the apple grower in Rhode Island is obliged to contend, and it is an important matter to find some satisfactory means of controlling it. What is being done in this line will be explained in detail in the report of the horticulturist.

The observations upon the fruiting habit and the results of interpollination, in the case of bush fruits, have been continued.

The work in selecting, crossing, and in the growing of seedlings has been continued, with the hope, if possible, of securing new, hardy, and desirable varieties.

Experiments in corn selection are giving promise of much interest.

Concerning the attempts to propagate the swamp blueberry, it may be stated that many of them resulted in practical failure. Other methods, however, were found to be fairly successful, so that the investigation is in a promising stage. While it is obvious that this work may not be of particular interest to Rhode Island residents from the standpoint of growing this fruit here artificially, yet in many sections of the country it is not found in profusion naturally; and if satisfactory means of propagating from plants producing large and perfect fruit are developed, it is possible that they may lead to a new line of effort in the propagation and distribution of these plants in other sections of the country.

The endeavor to produce by selection, if possible, a more hardy type of bean which will better resist frost is still being continued. It can hardly be expected, even though progress in this line is possible, that sufficient advance can be made, even in a few years, to be noticeable to a striking extent.

In connection with strawberries, the work of selection, crossing, and the growing of seedlings for the purpose of securing, if possible, productive, hardy fruit of fine quality, is being prosecuted to as great an extent as the means and opportunities at disposal permit.

The work of clover selection, for the purpose of securing, if possible, the most satisfactory and hardy type of plants, is still being prosecuted.

A number of different kinds of vegetables are being grown under the cover of cloth, with complete protection, for the purpose of studying further the influence of this practice upon their growth.

The division is making plans to compare the relative effectiveness of large applications of stable manure and of chemical manures in the growing of garden vegetables.

Experiments are also planned to show, if possible, why the sterilization of soils in greenhouses is often ineffective. This involves re-inoculation of the sterilized soils.

Thus it will be seen that a varied and interesting series of experiments is in progress in the horticultural division of the Station. Further details in relation to the results of many of these experiments during the past year may be found in the report of the horticulturist.

DIVISION OF ANIMAL HUSBANDRY.

The biological division has continued, as in the past year, under the charge of Dr. Cooper Curtice. The work of this division is primarily in artificial incubation, the winter brooding of young chicks, together with the feeding of them, and investigations as to the manner of the transmission of the disease of turkeys known as the "blackhead."

During the previous year the experiments in incubation were successful and interesting, but unfortunately the attempts at artificial brooding during the winter months resulted disastrously in many cases. It was believed by Dr. Curtice that the chief source of difficulty was the inefficiency of the heating system, in consequence of which the young chicks were submitted upon certain occasions to a temperature which was, apparently, so low as to cause great mortality among them. In consequence of this a new steam heater was installed in the Experiment Station plant during the latter portion of the summer of 1903, by means of which it has been possible, during the past winter, to control the temperature conditions in a satisfactory manner. It is a pleasure to be able to report that in certain of the experiments in artificial brooding, even during the most inclement periods of the winter, all of the chicks which were taken from the shell were readily reared to the broiler size, and in the most unfavorable cases the mortality has seldom risen above twenty per cent. In other words, Dr. Curtice has apparently demonstrated beyond a question that the great losses of young chicks, particularly during the winter months, which have been reported to this Station by letter in innumerable instances during the last few years, may probably be prevented if suitable temperatures are maintained—and provided proper attention is given to the feeding. It was found in the course of the experiments that certain malformations of the breast and other bones of chicks, which resulted under certain conditions of feeding, could be prevented entirely when the proper foods were employed.

Concerning the "blackhead" disease of turkeys, it may be said that during the preceding year attempts were made both in North Carolina and Virginia to purchase eggs which could be used in experimental work, and notwithstanding that four counties in Virginia were canvassed for this purpose, it was impossible to secure from the growers a proper supply of eggs. In consequence of this disinclination to sell turkey eggs negotiations were commenced, in the early fall of 1903, as a result of which the Station secured a tom turkey and several females from a section in North Carolina, and also in Virginia, where the "blackhead" disease was supposed not to exist. An additional lot of turkeys from Rhode Island, where diseased animals had been present, was also secured. The turkeys from the south have been placed in large pens prepared for the purpose, at a point remote from the Rhode Island animals.

It should be mentioned that two years ago evidence was adduced to the effect that the organism which caused the "blackhead" disease was probably transmitted through the eggs, in the case of animals which had already had the disease and recovered, or else that it was transmitted to young poults by ordinary fowl or some other form of animal life with which they came in contact. The turkeys from the south are at the present time enclosed upon land which has not been occupied by ordinary fowl nor by other turkeys for a long time, and it is so located that there is no possibility that the organism can be introduced into the pen through washing from other portions of the poultry yard, owing to the fact that it is located upon higher ground than the rest of the poultry plant. If turkeys can be raised effectually in these enclosures without acquiring the disease, and if the same eggs when hatched under and reared with ordinary fowl, bring forth poults which subsequently die of the disease, then the evidence that the organism which produces it is conveyed by ordinary fowl will be very strong. Dr. Curtice reports that he has discovered in some of the fowls in the poultry plant a disease affecting the liver in a manner very similar to that of the organism which causes the "blackhead" disease of the turkey. Though whether it is positively identical with the latter or not has not been determined, nor is it known whether the organism taken from the fowl and introduced into the turkey will surely produce the "blackhead" disease. Whether by removing the ordinary fowl and turkeys from a given section for a year or more, and then restocking from regions where the "blackhead" disease does not exist, one may entirely escape the trouble, is a point which it is interesting to determine. It must be obvious that if ordinary fowl are carriers of the organism which produces the "blackhead" disease in turkeys, then it will be necessary to rear chickens artificially if kept upon the same areas in order to have both remain free from the disease. If it should be found that the organism is transmitted through the eggs, then it will also be necessary to secure eggs from animals in which the organism does not exist.

Enough has been said to show that this line of work is highly interesting, and that there is a possibility of its leading to results of great practical value. The work is necessarily somewhat complicated and tedious, and it must not be expected that definite and positive results can be obtained in two or three seasons. In order to prosecute this line of investigation satisfactorily, the Station should have at its disposal lands in certain sections of the State where neither turkeys nor ordinary fowl can gain access to them, and means should be afforded for fencing additional enclosures at the Station where special phases of the subject can be studied. Owing to the limitations placed upon the expenditures of the fund derived from the Hatch act, only a small amount of money is available each year for the purpose of fencing; hence, if the Station is to be put in a position to prosecute this work as vigorously as is desirable, financial aid from the State will be necessary. Special attention has been given here to this line of work which Dr. Curtice is conducting, for the reason that it is believed that the rehabilitation of the turkey industry in Rhode Island is of the greatest interest to every resident of the State, not only on account of the recent high market price of turkeys, but also because it was formerly a very remunerative industry and one which incidentally added to the reputation of the State, not only at the White House, but throughout the country, generally.

DIVISION OF AGRONOMY.

The charge of the work in this division rests in the hands of the director of the Station, who is ably assisted by Mr. George E. Adams.

One of the most important problems which this division of the Station has to consider is the best and most economical means of renovating and of maintaining the fertility of the worn-out lands of Rhode Island, especially where stable manure cannot be obtained for the purpose or where the supplies available are very limited. If such lands within the State can be renovated only by the use of stable manure, then the prospect of renovating them in the near future is most disheartening, and a great loss of opportunity to Rhode Island farmers and a consequent loss of revenue to the State must inevitably result. If, on the contrary, these lands can be renovated by means of chemical manures, and if by their use the fertility can be permanently maintained, then there are still unlimited opportunities for agricultural enterprise in Rhode Island so long as artificial manures are sold at a reasonable price. If such conditions are found to prevail there is no reason why the exhausted soils of Rhode Island should not be renovated and the revenue of the State be greatly increased in consequence. In the study of this problem six different crop-rotations have been in progress for several years. These are essentially as follows:

Three-year Rotation.—The three-year rotation embraces clover, potatoes, and winter rye, and is carried on solely with the aid of chemical manures. It has been found that this rotation is very satisfactory if the seasons are favorable; but if a severe drought occurs during the year when the rye is grown, the young clover plants are in danger of being entirely destroyed. If a severe drought occurs during the latter part of May or in June of the next succeeding year in the rotation, then the clover, which is the crop of that year, is likely to be seriously affected, and the yield may be so greatly reduced, even though the conditions of the previous year were favorable, that it may not prove profitable. Grass is not likely to be destroyed by drought, particularly if top-dressed early in the spring with suitable chemicals, while there is still abundant moisture in the soil; hence a good crop can usually be obtained even in dry seasons. In view of these facts it has seemed wise to sow grass seed with the winter rye, so that the land in the year succeeding the rye crop will be occupied by clover and grass instead of being devoted solely to clover. If the clover fails, a crop of grass may then be secured.

Four-year Rotation.—The four-year rotation includes Indian corn, potatoes, winter rye, and clover. What has been said concerning the clover crop in the three-year rotation applies with equal force to this one. In this rotation, the Indian corn crop is raised with the aid of stable manures, the manures for the other crops being wholly artificial.

Five-year Rotations.—Two five-year rotations are being conducted which are identical with the exception of one particular, namely, in one common red clover is introduced, and in the other it is omitted. The order of rotation where the clover is omitted is as follows: Indian corn, potatoes, winter rye, grass, grass. Where the clover is included it is the same, with the exception of the fact that clover and grass follow immediately after the rye.

The third five-year rotation was designed by Ex-Director Flagg, and was planned to meet the requirements of a farm on the outskirts of the city where milk and vegetables were to serve as the chief source of income. It is as follows:

First year, clover;
Second year, potatoes;
Third year, winter rye for fodder, or bedding, followed by Hubbard squashes;
Fourth year, early peas, followed by Swedish turnips;
Fifth year, oats, seeded with clover.

The objection to the employment of the clover crop alone, mentioned in connection with the three-year rotation, applies likewise to this one. It has been found also that it is desirable to cut the rye early to prevent the removal of too much water from the soil, for otherwise it not infrequently happens that it is difficult to make the squashes succeed. Unfortunately the soil upon which the experiment is being conducted is not well adapted to the production of very early peas, nor is it porous enough to be well suited to Swedish turnips. On account of these reasons the substitution of onions for peas and Swedish turnips (rutabagas) is being considered at the present time. No stable manures are employed in this rotation.

Six-year Rotation.—This rotation is as follows: Indian corn, potatoes, winter rye, clover and grass, grass, grass.

One-half of the plots in this rotation are manured exclusively with chemical manures, and the others differ only in receiving stable manure for the Indian corn crop.

Concerning the two five-year rotations in which the land is in grass for two years, and the six-year rotation which has just been mentioned, it has been found that as a rule they are more likely to prove remunerative in the case of worn-out land which is in bad physical condition if rye is sown at the outset with grass seed, provided the grass is properly top-dressed. The chances of growing corn and potatoes at a profit at the end of the first course of the rotation are infinitely greater than at the beginning of the course. During the first three years of the rotation the crops of grass ranged in many instances from one ton to two and a half tons per acre, and only in exceptional cases were larger yields obtained. From other results in connection with grass culture it was ascertained that in all probability too small amounts of manure were used in top-dressing the grass, and the amounts were therefore increased in the year 1901.

Since then the average yields of field-cured hay from the plots in these rotations have been approximately four and one-fourth tons per annum. In some instances the individual yields have been about five tons.

In other words, it has been demonstrated that with a small increase in the cost of manures an enormous gain in the crops has resulted. In view of the possibilities of good profit from grass crops, and in order to test certain questions which have arisen, another rotation, designed to cover seven years, is now under consideration, which it is hoped will ultimately prove not only of great interest but also of much practical value to the farmers of Rhode Island.

The experiment upon the continuous growth of Indian corn by the use of chemical manures, with and without crimson clover and winter rye as catch crops, is being continued.

For about ten years experiments were in progress for the purpose of ascertaining the effect of soil acidity and of liming upon the growth of various agricultural plants. The plots upon which these experiments were conducted were kept in hoed crops for several years, and it was finally thought desirable to seed them to grass for the purpose of introducing more organic matter. In the spring of 1904 these plots were again plowed, and the trial of the effect of soil acidity and of liming upon various plants is being continued. Many of the plants employed at this time are such as have not been used heretofore or they are such as have given in the past, results which needed further substantiation. It is hoped that the continuation of these experiments will furnish data, not only of scientific interest, but also of direct practical value along several lines.

In connection with grass culture, a further trial is being made in the season of 1904 upon the same plots which have been devoted to that crop already for the five preceding years. Three plots are manured alike with potassic and phosphatic manures. One receives no nitrogen, another a moderate amount, and the third a large dressing. This particular experiment is demonstrating rapidly what is the most economical amount of nitrogen to employ in grass culture upon a soil which is typical of the major portion of the better grass-lands of Rhode Island. Supplementary to this experiment, a trial is being made of different amounts of potassium salts in the presence of like amounts of nitrogenous and phosphatic manures. Another comparison is being made of different amounts of phosphatic manures in the presence of like amounts of nitrate of soda and potassium salts. These two experiments, together with the one mentioned previously, will, it is hoped, show what is probably the most economical combination of manures for use in top-dressing grass-lands.

To further enable the Station to answer questions which are being continually raised concerning the treatment of grass, arrangements have been made for making comparative trials of the efficiency of phosphorus as a top-dressing for grass, when applied in finely ground bone, guano, basic slag meal and acid phosphate. In previous grass experiments made at this Station most of the phosphorus has been applied in acid phosphate, and it is desired to ascertain if basic slag meal, guano, and bone are as desirable and economical sources of that element, for grass, as acid phosphate.

Further trials of a few varieties of potatoes which have been recommended or which seem promising, are being made. It is planned also to study further the question whether it may be profitable for Rhode Island farmers to embark in the growing of German salad potatoes.

It is planned to continue the experiment conducted for the purpose of securing, if possible, cowpeas which will ripen their seed in our climate.

The trial of a number of different kinds of phosphates upon both limed and unlimed soil, which was begun about ten years ago, is being continued the present season, though in this case, with only a single crop. It was demonstrated in this experiment, in 1903, that ignited iron and aluminum phosphate, which appeared by chemical analysis to have been of much value and which is given a high classification in ordinary commercial fertilizers, was practically worthless for most plants upon acid soil, particularly so far as concerned any after-effects. Previous experiments with it have shown that upon newly limed soil, for grass, it was nearly as effective as some of the best phosphatic manures. It is believed that a continued study of the action of this and other phosphates which are employed in the manufacture of our ready-mixed commercial fertilizers will throw much light upon the relative practical value of these phosphates for various plants and prove ultimately of great service to the agriculture of this State.

The experiments in connection with soda, for the purpose of ascertaining with what plants and under what conditions it is beneficial, as well as the reason for such benefit if it results, are still being continued. From what has already been ascertained it is believed that where soda is present in the soil there results, in the case of certain plants which can take up soda to a considerable extent, a conservation of the potash supply of the soil.

During the season of 1903 an experiment in soil inoculation, for the soy bean, was undertaken at East Providence. For this purpose, one of the cultures prepared by the Department of Agriculture, and some soil from Kingston, where the soy bean had been grown previously, were employed. Both seemed to have worked successfully so far as concerned their effect upon the growth and appearance of the plants. In the case of the culture from Washington, few, if any, nodules developed upon the roots, while they were abundant in the case where the soil was inoculated with earth taken from Kingston. The owner of the farm at East Providence, where the soil was inoculated for the soy bean, has now kindly volunteered to give to other farmers in the vicinity lots of his soil, in case it is desired, for purposes of inoculation.

SPECIAL SOIL INVESTIGATION.

In the course of the various experiments that have been conducted from time to time at this Station for the purpose of ascertaining the influence of lime upon plant growth, the idea has suggested itself that the lime might possibly be advantageous by virtue of its promoting the growth within the soil of certain fungi and bacteria aside from those organisms which promote nitrification and which enable certain plants to assimilate atmospheric nitrogen. For the purpose of securing, if possible, a clue as to future lines of work in this direction which it would be desirable to pursue, should the means of the Station permit, arrangements were perfected with Mr. Latham Clarke to undertake some preliminary investigations during the summer of 1903. Both acid and alkaline culture media were prepared. Each of these was inoculated with infusions prepared from the different soils. One of these soils was in a very acid state, and among other manures had received annual applications of sulfate of ammonia for several years. The other soil had been treated in an identical manner, with the exception that lime had been applied previously. It was found that where the alkaline medium was inocluated from both soils, only a limited number of different cultures was obtained from the acid soil, as compared with the number from the soil which had been limed. On the contrary, when inoculating an acid medium from the limed and unlimed soil, a larger number of different organisms was obtained in the case of the unlimed soil. The number was, in fact, comparatively limited in the case of inoculation from the soil of the limed area.

This preliminary investigation was sufficient to show that the chemical reaction of the soil had within a few years effected a very marked difference in the character of the fungi and bacteria represented in the soils. Unfortunately the Station has not the means at the present time to follow up this investigation, but it is hoped that if the opportunity is ever afforded to make a study of the special organisms which are found upon each of the two classes of soils to prepare pure cultures of these, and, if possible, ascertain in what way, if at all, they may be of any agricultural value. It is possible that organisms may be recognized which are disadvantageous, and hence indications may be secured as to the best treatment of soils so far as concerns their elimination.

This brief statement is made merely to show the possibilities of such work and to indicate that it is the desire of this Station to pursue studies in this line.

POT EXPERIMENTS.

The pot experiments conducted during the past year have been limited to two or three lines. This limitation has been necessary owing to the lack of means for conducting the work upon a larger scale. An attempt was made to secure a neglected soil which had not been under cultivation, if at all, for many years. One series of pots filled with this soil was inoculated with infusions from certain of the experimental plots and another series remained uninoculated. It was thought that possibly organisms might be introduced in this manner which would prove of value either directly or indirectly. All that can be said of the first season's results is that they were wholly inconclusive. The subject is, however, not without interest and it is hoped to pursue it further in the future under more favorable conditions. It is a well-known fact that inoculation of certain soils with the organisms which enable certain plants to assimilate atmospheric nitrogen, has been resorted to successfully and it appeared probable that the introduction into the soil of still other organisms might prove advantageous.

The experiments in connection with the assimilability of nitrogen from various sources are still being continued.

CHEMICAL DIVISION.

The work of this division during the past year has been, primarily, the analysis of commercial fertilizers and feeding-stuffs in connection with the State inspection of these substances. It will be borne in mind that this work is paid for in the case of the fertilizer inspection by fees paid to the State by the manufacturers, and in the case of the feeding-stuff inspection by a State appropriation of $1,300 per annum. The Experiment Station is simply reimbursed for the time and materials employed in the inspection work, so that neither inspection serves as a source of revenue to the Station. Aside from this routine of analytical work, analyses of manurial substances have been made for other divisions of the Station in connection with the work of investigation.

The analysis of a number of lots of plants grown under various conditions has been made for the purpose of throwing further light upon the question of the agricultural importance of sodium and magnesium. An examination has also been made of the hay grown in certain of the grass-culture experiments, for the purpose of throwing additional light upon the field experiments, and in order that suggestions as to the greatest possible economy in the use of artificial manures might be secured. As time advances, the importance of analyzing all of the corps grown in the various plant rotations, for the purpose of ascertaining the amount of manurial substances removed, becomes more and more important; and the means ought to be available for carrying out this line of investigation.

In the course of the experimental work which has already been performed in connection with certain phases of the question of the agricultural significance of magnesium, a number of lines of very profitable inquiry have suggested themselves which will involve work in the chemical division; thus this division is often of the utmost importance in throwing light upon what has transpired in connection with the growth of plants in both field and pot experiments.

PUBLICATIONS.

The publications for the year beginning July 1, 1903, and ending June 30, 1904, are as follows:

Bulletin No. 95, July, 1903, "Co-operative Experiments in Top-Dressing Grass-Land." 19 pp.

Bulletin No. 96, August, 1903, "Influence of Lime upon Plant Growth." 24 pp.

Bulletin No. 97, October, 1903, "Commerical Fertilizers." 16 pp.

Bulletin No. 98, January, 1904, "Analyses of Feeding-Stuffs." 20 pp.

Bulletin No. 99, April, 1904, "A Six-Year Rotation of Crops. 39 pp.

Bulletin No. 100, May, 1904, "When to Spray—Formulas and Notes on Spraying." 29 pp.

Bulletin No. 101, June, 1904, "Analyses of Commercial Fertilizers." 12 pp.

The demand for the Station publications, not only within Rhode Island, but also in the various States of the Union, has increased steadily during the year, so that, notwithstanding the recent revision of the mailing list, an edition as large as before the revision, is still necessary to supply the regular demand.

CORRESPONDENCE.

All that has been said in previous years in relation to the gradual increase of the correspondence, chiefly in the way of inquiries for agricultural information and assistance, can be repeated with emphasis. It is unfortunate, in certain respects, that the number of demands in this line is so great, on account of the interference with time which Station workers might otherwise devote to investigation; yet, as has been said upon previous occasions, these inquiries are largely the results of what the Station has done experimentally in the past, and the replies sent out have obviously been of great assistance to farmers. The chief lines of inquiry, as heretofore, have been concerning soils and manures, the treatment of fungous and insect pests, and questions concerning the management, care, and feeding of poultry. This work should be provided for, in so far as possible, in connection with the agricultural demonstration and extension work of the colleges, in order that the scientific workers may have more time for carrying on research work.

LIBRARY.

The library has been increased somewhat during the past year, and the current periodicals have been duly bound. The library of the Station is quite complete in many respects, yet if means were available it could be profitably enlarged by the addition of a number of foreign periodicals which contain frequent articles bearing very directly upon the work which is being carried on by the Station. Such additional periodicals would be of great help in still further placing in the hands of the Station staff the means of keeping in-formed as to the latest investigations that are being conducted in other countries.

It is urgently requested that any parties in the State who are in possession of any of the earlier bulletins and reports of the Station, which they do not care to preserve, will put themselves in correspondence with the Station. Many of the earlier publications are entirely exhausted, and hence some of them already have a market value. In order to supply the urgent demand for these publications which come from time to time from libraries, the Station would gladly secure by purchase some of the earlier numbers of both reports and bulletins.

ADDITION TO THE STATION EQUIPMENT.

The additions to the Station equipment during the past year have been less than in each of the two years which immediately preceded. This is largely due to the demands made upon Station resources in connection with experimental work and in part due to the fact that the various divisions have already become much better equipped for their work than previously. So far as possible an attempt has been made, in increasing the equipment, to maintain each of the various divisions in a high state of efficiency and to avoid the undue weakening of one and the special strengthening of another.

THE NEEDS OF THE STATION.

Concerning the needs of the Station at the present time, it is desirable to emphasize in the strongest language possible what was said in the last annual report concerning the need of a set of poultry buildings for the use of the College, so that the work of experimenting in connection with the rearing and feeding of young chicks during the winter months should not be interrupted, as has heretofore been the case, on account of the necessity of utilizing the incubator and brooder house for the benefit of students during the short college course in poultry culture.

What has been said in previous reports in regard to the desirability of dividing the work of the College and Station employees so that those who are entrusted with the investigation of scientific problems may do no more than a very limited amount of teaching in the College is again emphasized. It is practically impossible for one who is obliged to teach several hours a day during the year, and who has charge of more or less practical work connected with the College, to concentrate his attention for sufficiently long periods upon the work of investigation and to prepare such work for publication so as to make it satisfactory and profitable in the highest degree.

The hope is still expressed that the Station may sooner or later be provided with suitable greenhouses, so that the work of investigation which can only be carried on under glass, can be pursued. This is particularly desired in case additional means are placed at the disposal of the Station for conducting investigations. If such a house were provided, and the means of the Station were sufficient for doing the work, the demands for assistance coming from those engaged in growing plants under glass and in truck farming could be met with manifest advantage to the State.

A pressing need of the Station is a suitable dry and fire-proof vault, where the records of the various experiments can be suitably housed.

STATION STAFF.

During the year no changes in the personnel of the heads of divisions have resulted. This has been in many respects a very distinct advantage to the Station, and there has consequently been no interruption in the continuity of the work in progress.

Early in the year Miss Mary G. Schermerhorn, who had most acceptably filled the position of stenographer and librarian, resigned, and her place has been filled successively in the interim by two other stenographers. It gives me pleasure to give special credit to Miss Ethel M. Chadwick, who has occupied the position for several months, and whose withdrawal occurs just at the close of the year.

Miss S. Aline Nye, stenographer and accountant, tendered her resignation in December, 1903. Miss Nye had been connected with the Station for a number of years and was a most efficient and faithful worker. The position made vacant has since been filled by the appointment of Miss Beulah A. Hoitt.

The resignation of Mr. A. W. Bosworth, in February, 1904, for the purpose of accepting a position in the United States Department of Agriculture, rendered it necessary to secure a successor. Mr. A. G. Lauder, of Cornell University, was employed to fill the position, and he assumed his duties on March 15. About two months later he in turn resigned, to accept another position at a greatly increased salary. The position thus made vacant has been filled by the temporary appointment of Mr. H. M. Soper, a graduate of the University of Maine.

ACKNOWLEDGMENTS.

It is a source of satisfaction to acknowledge the united and hearty support, during the past year, of the heads of the divisions and their assistants. The spirit of harmony and co-operation which exists is one of the hopeful features connected with the outlook for the ensuing year, since without its existence it is impossible to secure the best and most efficient work and to insure the greatest returns for the efforts put forth.

In conclusion it gives me pleasure to acknowledge the hearty support of the Board of Managers in the efforts made to place the work of the Station upon as efficient a basis as possible.

Respectfully submitted,

H. J. WHEELER,

Director.

HORTICULTURAL DIVISION.

REPORT OF THE HORTICULTURAL DIVISION.

FRED W. CARD AND A. E. STENE.

THE APPLE-MAGGOT.

(*Trypeta pomonella*, Walsh.)

The apple-maggot is one of our most troublesome orchard pests in Rhode Island. Much of the fruit grown in the State is entirely worthless, owing to its ravages. This is the pest, also known under the name of the railroad worm, which tunnels all through the flesh of the fruit, thus rendering it absolutely worthless and transforming the eating of an apple from a pleasure to a dread. Unlike most orchard pests, this one can not be controlled by spraying. The egg is deposited beneath the skin of the growing fruit, beyond the reach of any spray. The fruit of a well-sprayed orchard may, therefore, be as badly injured as that from an unsprayed one. Some other method of attack must be chosen. It has been with the hope of finding some such effective method that the experiments here described have been carried on.

The life history of the insect was carefully worked out by Professor Harvey, of Maine.* In brief, this life history is as follows: The parent is a two-winged fly (Fig. 1), a trifle smaller than the house-fly. Its wings are distinctly marked with irregular black bands, and are held in a peculiar half-raised position. The earliest date at which we have known flies to emerge in our experiments here is July 2d. During the season of 1902 we found none until nearly the end of

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* Maine Experiment Station Report, 1889, page 190.

July. It is probable that the date at which they emerge may be influenced by the date of ripening of the fruit from which they came, but this is an unproved supposition. By the middle of July, in an average season, early apples of varieties commonly affected will show very many of the punctures of this fly. These punctures appear merely as small black specks, oftentimes showing a slight depression from arrested growth. They are much smaller and less noticeable than the wounds made by the curculio.

The development from the egg stage seems to be largely influenced by the development of the fruit. The growth appears to be very slow until the fruit begins to ripen and grow soft. Oftentimes there is but little progress until the fruit falls from the tree. After attaining its growth the larva leaves the fruit, enters the ground, and changes to a pupa. This pupa is much like a kernel of wheat in size and general appearance. We have found pupæ as early as September first, but this was from early fruit. From late varieties they must enter the ground much later. No flies emerged during the same season from the pupæ found thus early, and apparently there is but a single brood each year. In entering the ground the little worm seldom, if ever, goes more than one inch deep, usually less. Oftentimes they may be found among the grass roots or just beneath decaying fruits. In this position they remain until the flies come out the following year. As stated above, this is in July, or later, with us.

The only remedy which is known to prove effective against this insect is that of destroying the windfalls as soon as they drop, either by pasturing the orchard or by picking up and destroying the fruit. Under some conditions, this is a feasible remedy, but under others it is not. The system of orchard culture commonly followed at the present day involves thorough cultivation of the orchard during the early part of the season, with a cover-crop occupying the land during the latter part of the season. This system of management does not admit of pasturing, and to pick up and destroy all windfalls is too troublesome and expensive. This same difficulty holds with the sys-

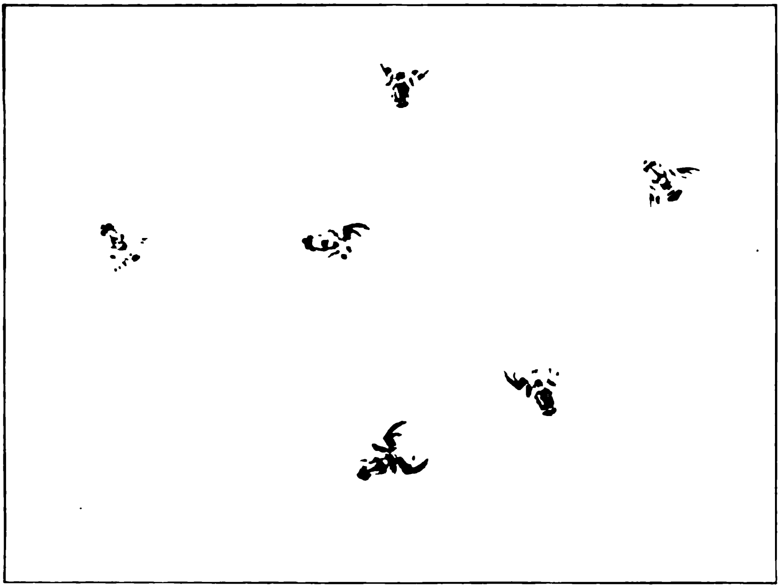

Fig. 1.—The Apple-maggot Fly.

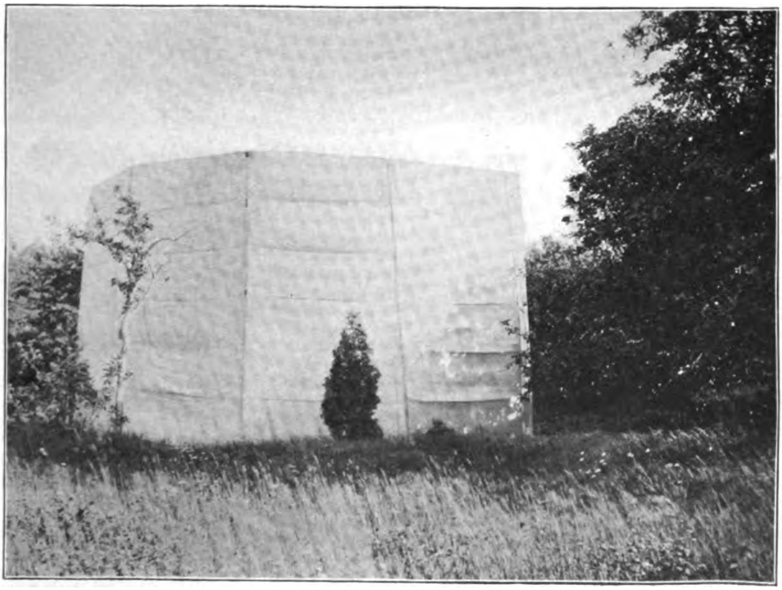

Fig. 2.—Tent covering used in 1902.

tem of grass mulch, which is being strongly advocated by some growers at the present time. It seems desirable that some other point of attack should be found.

Professor Harvey, in his admirable monograph, previously cited, suggested that plowing the orchard fairly deep ought to prove an effective remedy. Since the fly is not a strong appearing insect, and the larvæ never go more than one inch deep to pupate, he reasoned that the flies would not be able to emerge through four or five inches of soil. Some observations in our earlier work seemed to indicate that this supposition might be correct. In connection with the experiments in improving an old orchard, reported in Bulletin 83, it was observed that the damage done by this insect was less in the cultivated orchard, than in uncultivated ones.

In 1899 two trees in an orchard near the College, each of which had been badly infested with the apple-maggot the previous year, were covered with cheese-cloth. Under one of these trees the ground was thoroughly spaded, turning the soil over to the depth of a spade-blade as nearly as possible. Under the other the ground was left undisturbed. A strong wind-storm tore these covers from the trees before it was possible to determine the effect of the treatment.

In the second experiment the ground underneath the trees in one end of an orchard was plowed about six inches deep in the spring, and given clean cultivation thereafter. In the remainder of the orchard the ground was left undisturbed. On September 19, 1899, five hundred apples of "White Seek-no-Further" and "Golden Ball" from the tilled portion of the orchard and five hundred apples of "Late Strawberry" from the untilled portion were examined. Of these fruits two hundred thirty-six, or forty-seven per cent., from the tilled portion contained maggots. From the untilled portion, three hundred ninety-four fruits, or seventy-eight per cent., were maggoty. These trees were so near together that there would be little to hinder the flies from passing from one to the other, but the results seemed to indicate an advantage for tillage. Many of the fruits from the tilled portion were but slightly injured, while many of those fruits from the untilled portion were badly damaged. It is quite possible that one variety may have been more susceptible than the other, for varieties differ greatly in this respect.

In the year 1900 the results in this orchard were much less promising. Notes made September 17th say that fully seventy-five per cent, of the apples then ripe seemed to be affected, though in some cases the injury was not so great as to wholly destroy the fruit. This seemed to indicate that we had been over-sanguine in the hope that spring plowing might prove a remedy. The orchard had been plowed in the spring of 1900, but the tillage had not been good. The soil of this orchard is light and sandy, and it was thought that plowing might be less effective here, than under different conditions. It was also true that trees nearby were standing in sod, and flies might easily spread from them to the orchard.

The experiment in covering trees with a tent was again repeated in 1901 in the orchard where it had been tried two years before, though in this case but a single tent was used. The ground underneath this was carefully spaded to a depth of six inches, taking care to turn the surface under as much as possible. The fruit of this tree had been badly infested the previous year. This tent was injured in a storm July 2d, but was repaired July 5th and 6th. It should be observed that the presence of this tent prevented flies from other trees in the orchard from reaching this tree, and any which emerged from underneath the tree must come from ground carefully spaded. The variety chosen was a sweet apple, ripening in summer, one which was commonly very badly infested. On August 17th thirty apples from this tree were examined, and eight of them found injured. On August 21st fifty apples were examined and ten were injured, while fifty apples of the same variety from an adjoining tree were all badly infested. Further examinations, made during September, showed that the apples underneath the tent were practically free from maggots, while those from an adjoining tree were entirely ruined.

This result seemed to indicate more strongly than those in the tilled orchard that thorough plowing would control this pest, but later developments showed that we had failed to reckon with one important factor. We knew the fruit of this tree to have been badly infested the year before, but the orchard is a small one, and the owner takes great interest in it. It is his custom to pick up and feed to the hogs fruit which falls. This being a sweet apple, was particularly suitable for this use, and from later inquiry it seemed probable that most of the fruit from this tree had, the year before, been so gathered and fed. In that event there would be few pupæ there to emerge. The fruit under the tent was noticeably retarded in ripening, and the question arose whether the shade of the tent itself might have any influence upon the work of the maggots.

During the season of 1902 several inquiries were under way. The soil of this entire orchard, where the tent had been in 1901, was turned under to a depth of about six inches. A plow was used, where possible, and the remaining land spaded. The land under trees nearby, about the buildings, was also carefully spaded. This work was finished before May 15th. The nearest apple-trees, under which the ground had not been turned, were those of a neighbor whose orchard was located something like one-fourth of a mile away. Even this orchard was plowed by its owner, but doubtless some of the ground about the trees was not turned under. The results were discouraging, but decisive. While the fruit did not seem so badly affected as in the neighboring orchard, the early sweet varieties were practically worthless, at least soon after falling from the tree. It seems to be the general rule with these early varieties that the larva does not develop to any extent until the apple ripens and falls. This season a tent was put over a tree in an orchard without disturbing the ground underneath. (Fig. 2.) The remainder of the orchard was plowed by the owner. The object of this was to determine whether the favorable results obtained under the tent the previous year had been, in any way, due to the effect of the tent itself. The variety used in this experiment was Porter, the fruit of which had been badly infested the previous year and allowed to lie on the ground undisturbed. This tent was finished June 24th. Examinations made during August and September showed the fruit from this tree to be as badly infested as that from an adjacent Porter tree which had not been covered. This answered our question and showed that the influence of the shade produced by the tent had no effect in checking the work of this insect.

In the third line of investigation a number of pupæ were gathered from an orchard about May 1st. These were kept in a pot of soil in the greenhouse until May 26th, when they were removed and buried at different depths outside. The soil in this pot had been allowed to get somewhat dry, but nearly all of the pupæ seemed moist when removed. Drain tiles were set in the ground, the earth pressed about them, and also lightly pressed inside.

Seven tiles were used, and the pupæ were buried within them as follows: In tile No. 1 they were placed just beneath the surface. In tiles Nos. 2, 3, 4, 5, 6, and 7 they were buried 1, 2, 3, 4, 5, and 6 inches deep, respectively. The earth over them was lightly firmed, but not pressed hard. Six pupæ were placed in all the tiles, except No. 7, in which there were only five. Lantern globes, imbedded in putty, were placed on the top of these tiles, and gauze cloth was tied over the globes. (See Fig. 3.) A careful watch was kept, but no flies were seen until July 28th, when one was found in each of the globes in which the pupæ had been buried 1, 3, 4, and 6 inches deep. They continued to emerge from time to time, from this date until August 11th. The entire number which emerged from the different depths was as follows:

Buried just beneath the surface	5
Buried one inch deep	6
Buried two inches deep	5
Buried three inches deep	6
Buried four inches deep	5
Buried five inches deep	4
Buried six inches deep	4

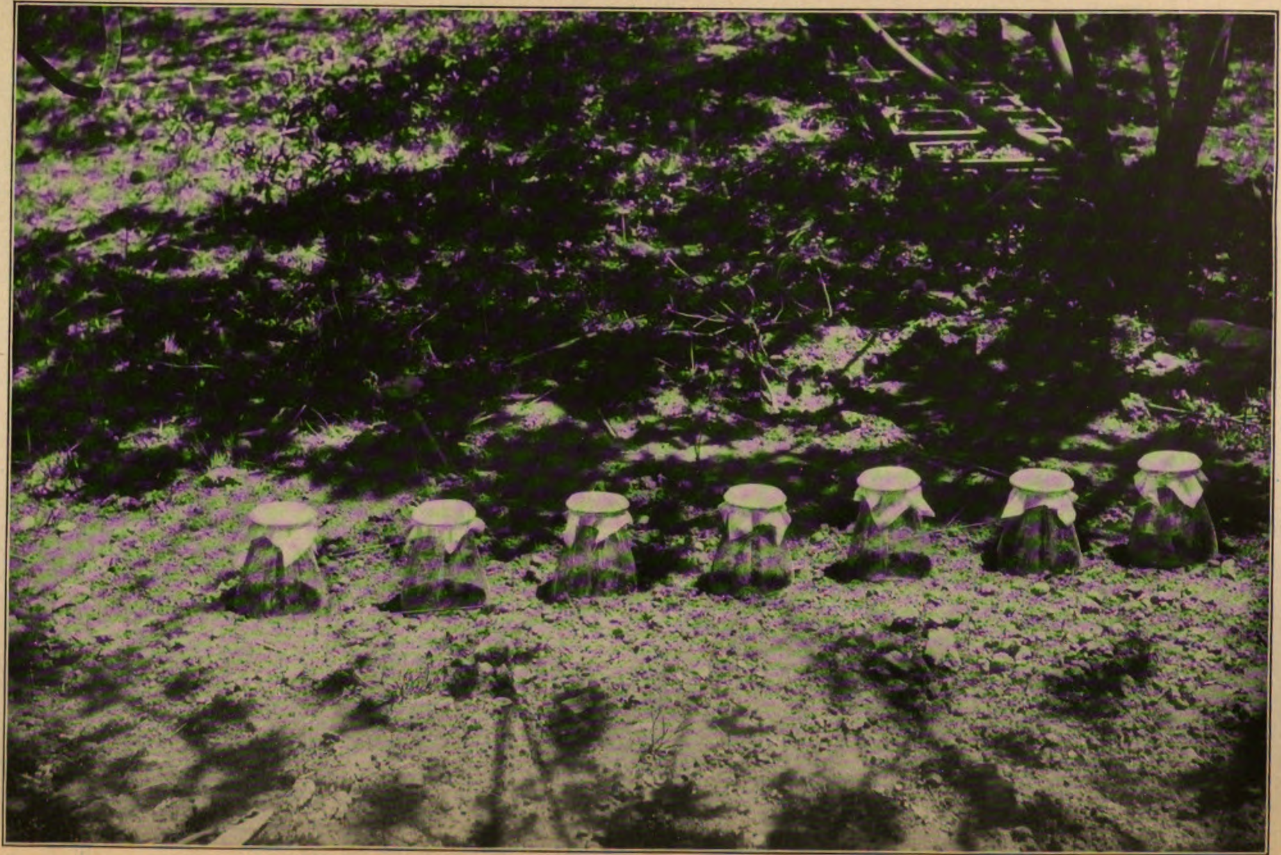

Fig. 3.
Lantern globes covering drain tiles within which pupæ were buried.

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These results fully corroborate those obtained by plowing and spading the entire ground in the orchard referred to. Apparently the flies emerged nearly or quite as well when buried six inches deep as when near the surface.

When Early Harvest apples were ripening, a number of infested ones were thrown into a box which had a layer of soil in the bottom. Setpember 1st these were examined. At that time the apples had entirely rotted. A few pupæ and a few maggots were found. Most of the pupæ were found just beneath the surface of the soil, although this was perfectly mellow soil thrown into the box from a garden. In one or two cases a larva or pupa was found in a little channel between the apple and the soil, but not entering the soil deeply enough to make any other covering for the channel than that of the apple which lay above. The few larvæ seen seemed to vary considerably in size, as though some had not been able to complete their growth before the apple rotted. In none of our observations were pupæ found in the decayed fruit itself, which remained on the ground over winter.

A number of the pupæ and some larvæ found in this box were placed together in one corner of it, and covered lightly with soil the following day. A glass dish was placed over them to prevent the escape of flies, if any should emerge. This was done to determine if a second brood might possibly appear from these early developed pupæ, but no flies emerged.

The experiment in burying pupæ at different depths was repeated in 1903, under somewhat different circumstances. The pupæ were buried just beneath the surface, and at 1, 2, 3, 4, 5, and 6 inches deep, as in the experiments of the previous year. In 1903 they were buried by digging a square hole six or eight inches across to the desired depth. The pupæ were then dropped into the bottom and the hole filled; the earth being pressed gently as filling progressed. The places were then covered with board frames with wire netting on top. (Fig. 4). Ten pupæ were placed under each frame.

Under a larger frame, two feet wide and three feet long, fifty pupæ were buried to a depth of about one inch or a little less. The ground underneath this frame was stirred from time to time to secure conditions similar to those in a cultivated orchard. It so happened that after the pupæ were buried there was an unusual amount of rainy weather, so that the ground had little opportunity to dry out. The conditions were not, therefore, favorable for this experiment.

Under a smaller frame, twenty-five pupæ were buried in a similar manner. To the ground underneath this frame kainit was applied June 9th. The amount used was ten grams, this being equivalent to about 1,000 pounds per acre.

Twenty-five pupæ were buried under a similar frame, to which crude petroleum was applied July 13th. A sufficient amount was sprinkled on to thoroughly wet the ground and the weeds which were growing inside the frame. Most of these weeds were killed.

Fifty pupæ were placed in a box in an office window, with about one inch of soil in the bottom of the box. This soil was moistened from time to time, being allowed to become thoroughly dry in the intervals. Later on it was allowed to remain dry. The pupæ used in these experiments were taken from a box containing about one inch of soil into which infested apples were thrown the previous autumn. The pupæ used were apparently in perfect condition though in removing them from the soil a number of empty cases were found. These cases appeared as if the insect might have been destroyed by some parasite. The pupæ were removed from this box and placed under the conditions above described on June 7th.

In addition to these, a few pupae were obtained from underneath a tree of winter apples and buried by themselves. Only three flies emerged from these. These three appeared late in the season, one July 24th, one August 1st, and one August 15th.

A careful watch was kept for the emergence of flies from the pupæ buried under these different conditions. The following table shows the number observed:

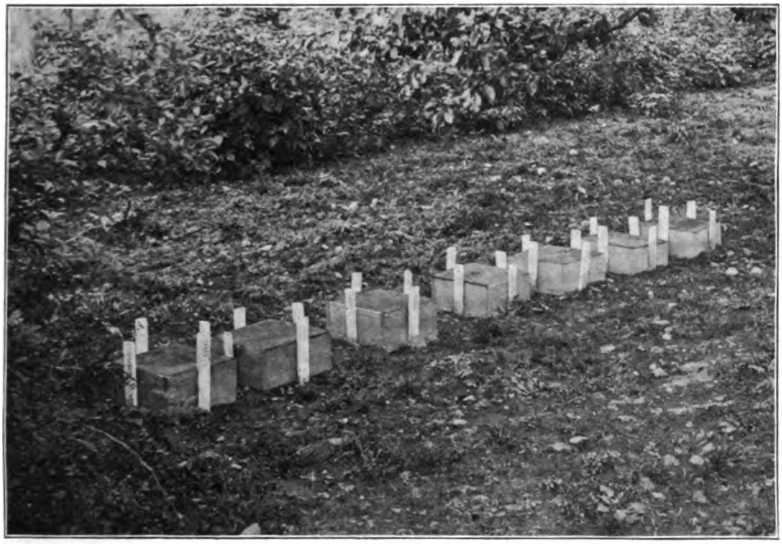

Fig. 4.—Frames under which pupæ were buried in 1903.

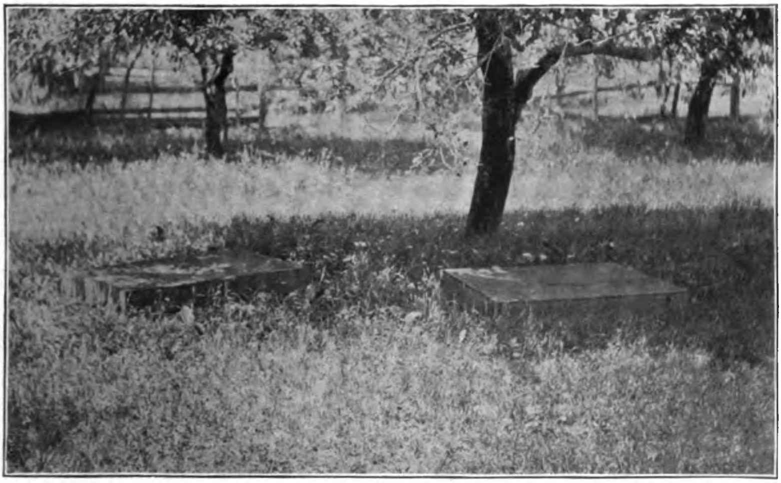

Fig. 5.—Frames covering spaded and unspaded soil in 1903.

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CONDITIONS.	No. pupæ buried.	No. flies emerged.	Percentage.
Just beneath the surface	10	5	50
Buried 1″ deep	10	4	40
Buried 2″ deep	10	3	30
Buried 3″ deep	10	1	10
Buried 4″ deep	10	3	30
Buried 5″ deep	10	6	60
Buried 6″ deep	10	2	20
Soil well stirred	50	10	20
Soil treated with kainit	25	9	36
Soil treated with crude petroleum	25	3*	12
Window-box	50	5	10

* Two of these emerged before the petroleum was applied.

In addition to these experiments in burying pupæ at different depths, four frames, 3x4 feet in size, were placed under trees in an orchard. (Fig. 5.) Two of these were placed under the Porter tree used for comparison with the tent-covered tree in the previous season's experiment. The other two were placed under a tree known to the owner under the name of "Fenner Sweet." This is a sweet variety ripening in the fall, and one which is badly attacked by the apple-maggot. The land under one of these frames beneath each tree was carefully spaded, as in experiments of previous years, while under the other it was left undisturbed. There is no means of knowing how many pupæ entered the soil, but most of the apples were allowed to decay on the ground the previous year, and they were badly infested with maggots. The first fly observed in any of these frames was under the Porter tree, July 2nd. The last one seen was under the "Fenner Sweet," August 24th. The total number which are known to have emerged from these frames during the season was as follows:

Frame beneath Porter tree, ground spaded	47
Frame beneath Porter tree, ground not spaded	45
Frame beneath "Fenner" tree, ground spaded	49
Frame beneath "Fenner" tree, ground not spaded	19

The results of this season's work corroborate fully those of the previous year, with regard to the effect of burying pupæ at different depths. It will be noticed that of those buried at known depths a larger number emerged from those buried five inches deep than from those buried at any other depth. While this is, of course, simply accidental, it shows that turning under the pupæ is not a remedy. This fact is further substantiated by the results just cited, which show the effect of spading land in the orchard.

Treating the ground with kainit is also apparently useless, at least when used in amounts which would prove economical. This has been advised in the treatment of some insects which spend a portion of their life in the soil, and it seemed possible that it might have some effect on the pupæ of the apple-maggot.

From the single test made with crude petroleum, it would seem that this might possibly prove of value, since only one fly emerged from the frame in which it was used, after the oil was applied. This may have been merely accidental, and other tests would be needed to determine if it is really of value. Not enough pupæ were available to permit of testing it again this season. Whether land could be sprinkled with crude oil cheaply enough to warrant its use, as is done in settling dust in some parts of the country, would need to be determined by trial. The question would also arise as to whether such an application would prove injurious to plants.

The conditions for testing the influence of tillage were unfavorable in 1903, but the results, taken in connection with those in the window-box, seem to indicate that disturbance and drying of the soil may be unfavorable to the development of the flies.

Spading land in the orchard is shown to be of no value, whatever. If any difference appears, it is apparently in favor of leaving the land undisturbed, since more flies emerged from those frames which were spaded than from those under which the ground was left undisturbed.

CONCLUSION.

Observation and experiments with the apple-maggot extending over a period of five years have thus far failed to disclose any remedy for controlling it, other than the one which has already been recommended, which is to destroy windfalls by picking them up or by pasturing the orchard. Plowing the orchard in spring, to turn the pupæ under, is shown to be valueless under the soil conditions prevailing here.

There is some ground for believing that frequent tillage in early summer may be unfavorable to the development from pupæ to flies. There is just a hint that sprinkling the ground with crude oil might be of value, if practicable. So far as we are able to suggest now, pasturing the orchard seems to be the only sure method of prevention in commerical work. Thorough tillage promises to be the next best method.

Clover Selection.

In the spring of 1903 an experiment was begun with a view to study the individuality of clover plants. An ounce of seed each of Medium Red and Mammoth clovers was ordered from the following seedsmen:

1. Joseph Breck & Son, Boston.
2. W. Atlee Burpee & Co., Philadelphia.
3. Henry A. Dreer, Philadelphia.
4. D. M. Ferry & Co., Detroit, Mich.
5. Peter Hendereson & Co., New York.
6. Northrup, King & Co., Minneapolis, Minn.
7. William Rennie, Toronto, Canada.
8. J. M. Thorborn & Co., New York.

Each lot consisted of one row of Medium and one row of Mammoth, as labeled by the seedsmen. A small amount of alsike clover and of alfalfa was also sown.

The seed was planted April 27th and 28th, in hills one foot apart, with rows three feet apart. Ten or fifteen seeds were dropped in each hill, and the plants thinned to a single one when about 2½ inches high. At the time of thinning an abundance of nodules was observed on the Medium and Mammoth clovers, and on the alsike, but none on the alfalfa. The alfalfa already showed a much stronger tap root than either of the others.

In September the following notes were taken upon the characteristics of the different plants.

Lot. No. 1. The plants have made a very uniform growth. Nearly all of them blossomed and have filled the space between the rows. This has made the best growth in the field, but is apparently all Medium Red.

Lot. No. 2. Plants very similar to those in lot No. 1, but not quite so large and strong. Nearly all are blossoming, but apparently all are Medium Red.

Lot. No. 3. The Medium Red plants are about like those in the previous lots, though perhaps not quite so vigorous, and not all are yet headed. Mammoth Red is true to name, with very few exceptions. An occasional plant along the row seems to be Medium Red.

Lot No. 4. True to name. Some of the plants are rather small, others strong and vigorous.

Lot No. 5. Mostly true to name. A few plants of Medium appear in the Mammoth row.

Lot No. 6. True to name. Both kinds look well.

Lot No. 7. Badly mixed, but apparently some Mammoth in the Mammoth row, though much of it is Medium. The Medium row looks well.

Lot No. 8. Badly mixed. Not much difference apparent between the two rows.

At this date most of the plants of Medium Red were in bloom. But few of the Mammoth had blossomed, although some had begun to throw up blossom stalks.

Some decided individuality of plant was to be seen. Many were still small and weak, with no sign of bloom. Others were strong and in full bloom. Some showed a very small tuft of leaves with small blossom stems, others large tufts with few or no stems. Some were light in color, others dark.

Various types were observed. One type was large with rank leaves, even on the blossom stalks; another type bore narrow leaves and small heads. There appeared to be a marked difference in the number of blossoms produced by different plants. The relative proportion of leaves and heads seemed to vary. A large number of heads, which would indicate heavy seed production, seemed to go with a smaller number of leaves, at least in some cases. The plants were observed to vary greatly in length of head, in color of blossom, in color and size of leaf, and in date of maturity. The gray markings on the leaves were much more prominent in some cases than in others. In some plants of Mammoth these markings did not show at all. Some difference was observed in the pubescence of the leaf. The difference in vigor and amount of leaf was often very pronounced.

Two plants of the different types described below were selected for chemical analysis.

Plant No. 1. A good, typical, dark plant, with large and numerous leaves, on which the gray markings were fairly pronounced. The stems were dark, but scarcely purple. Heads fairly good in number and size.

Plant No. 2. Leaves small and light colored, showing the gray markings but little. Leaves and stems very much lighter green than those of plant No. 1. Heads apparently about as good, with more of them mature at the time. Good seeds from plant No. 1 were a little darker in color than those from plant No. 2, but did not have the violet color often seen in clover seeds.

The protein content of these two plants, in an air-dried condition, as reported by the chemical department later, was as follows:

Plant No. 1	16.25 per cent.
Plant No. 2	16.63 per cent.

In these particular cases, at least, it seems that color of plant gave no clue to variation in protein content.

It has been often urged that a shorter corolla would be of advantage in red clover, for the reason that it would enable honey-bees and others to pollinate the blossoms. Bee-keepers are said to have made some attempts to increase the length of the honey-bee's tongue by selection and breeding. In studying these plants it was observed that honey-bees do work on the red clover, although not so freely as on alsike. None were observed at work on alfalfa, although some other bees were at work on it.

Many clover flowers were measured. The common length of corolla was found to be $6/16$ ($\frac{3}{8}$) of an inch, from the lower end as pulled out of the calyx to the little bunch near the top, at the point where the tube separates into lobes. There seemed to be great uniformity in this length of corolla. A few were found as long as $7/16$ of an inch, but none as short as 5/16, unless from some exceptional flower which did not appear to be well developed. Flowers from different parts of the head appeared to vary but little in length.

These plants were allowed to stand rather too long before cutting, and did not make a good second growth before winter. It was designed to leave them until the following year in order to observe their hardiness, and then save seeds from plants which seemed most promising. Unfortunately not a single plant of Medium, Mammoth, or alsike clover survived the unusual conditions of the past winter.* In this, they have suffered the common fate of all clover in our experimental grounds, for all the clover in the regular grass plots was likewise killed. Four or five plants of alfalfa lived through, from which it is hoped seeds may be saved. Other plantings have been made in 1904.

While the experiment shows no results as yet, it is recorded here for the purpose of calling attention to the fact of the great variations in clover plants grown from commercial seed. Not only is there individual variation, which is to be expected, but apparently much of the seed sold for Mammoth clover is not Mammoth clover at all. There is apparently good reason for taking every possible precaution to procure good seed, true to name.

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* This is the first time in the fourteen years since the experimental work of the Station was begun, that clover plants have been materially injured by winter-killing upon the Station farm.

CORN SELECTION.

The experiments in the selection of sweet corn begun in 1898 were continued, as heretofore, in the year 1903.*

This experiment was undertaken for the purpose of determining the influence of selection in increasing the number of ears per stalk. Two lines have been followed, one in which the seed which was planted was always taken from the lower ear from stalks producing the largest number of ears. In the other line, seed was always chosen from the upper ear of stalks producing the largest number of ears. This was done to test the theory sometimes advanced that since the lower ear is the last ear produced, and is always less perfectly developed than the upper ear, selecting seed from this ear will tend to intensify the habit of lower ear production, and consequently of the number of ears. The variety used in this work is Potter's Excelsior.

In 1903 the corn was planted May 27th. That in the lower-ear selection was put on ground occupied by bush-fruits the previous year. That in the upper-ear selection was put on land occupied by strawberries the year before. The kernels were dropped one foot apart in the row in order that the corn might stand at a uniform thickness. It was found the previous year that the number of stalks per hill appeared to exert an influence upon the number of ears per stalk. In the lower-ear selection only one small ear from a stalk which bore four ears, was suitable for planting. All of this seed was used, and the remainder needed was taken from lower ears produced by stalks which bore only three ears. In the upper-ear selection seed was taken from three upper ears produced by stalks which bore five ears each in 1902. A detailed record of the crop harvested in 1903, appears below:

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* See annual report for 1903, page 214.

Selection from Lower Ears.

Total number of plants	564	
Plants with no ears	104	(18.5 per cent.
Plants with one ear	212	(37.5 per cent.)
Plants with two ears	202	(35.8 per cent.)
Plants with three ears	31	(5.5 per cent.)
Plants with four ears	10	(1.8 per cent.)
Plants with five ears	3	(.5 per cent.)
Plants with six ears	1	(.2 per cent.)
Plants with seven ears	1	(.2 per cent.)
Total weight of ears		1,416 oz.
Total number of ears		777
Average weight of ears		1.82 oz.
Average number of ears per stalk		1.38

Plants Producing One Ear.

Total number of one-ear stalks	212
Total number of ears	212
Total weight of ears	368 oz.
Average weight of individual ears	1.73 oz.
Average weight of ears per stalk	1.73 oz.

Plants Producing Two Ears.

Total number of two-ear stalks	202
Total number of ears	404
Total weight of ears	808 oz.
Average weight of individual ears	2 oz.
Average weight of ears per stalk	4 oz.

Plants Producing Three Ears.

Total number of three-ear stalks	31
Total number of ears	93
Total weight of ears	152 oz.
Average weight of individual ears	1.63 oz.
Average weight of ears per stalk	4.9 oz.

Plants Producing Four Ears.

Total number of four-ear stalks	10	
Total number of ears	40	
Total weight of ears	88	oz.
Average weight of individual ears	2.2	oz.
Average weight of ears per stalk	8.8	oz.

Selection From Upper Ears.

Total number of plants	458	
Plants with no ears	10	(2.2 per cent.)
Plants with one ear	60	(13.1 per cent.)
Plants with two ears	157	(34.4 per cent.)
Plants with three ears	88	(19.2 per cent.)
Plants with four ears	75	(16.3 per cent.)
Plants with five ears	42	(9.2 per cent.)
Plants with six ears	15	(3.3 per cent.)
Plants with seven ears	8	(1.7 per cent.)
Plants with eight ears	3	(.6 per cent.)
Total weight of ears		3,384 oz.
Total number of ears		1,263
Average weight of ears		2.67 oz.
Average number of ears per stalk		2.76

Plants Producing One Ear.

Total number of one-ear stalks	60	
Total number of ears	60	
Total weight of ears	198	oz.
Average weight of individual ears	3.30	oz.
Average weight of ears per stalk	3.30	oz.

Plants Producing Two Ears.

Total number of two-ear stalks	157	
Total number of ears	314	
Total weight of ears	924	oz.
Average weight of individual ears	2.90	oz.
Average weight of ears per stalk	5.88	oz.

Plants Producing Three Ears.

Total number of three-ear stalks	88	
Total number of ears	264	
Total weight of ears	723	oz.
Average weight of individual ears	2.70	oz.
Average weight of ears per stalk	8.21	oz.

Plants Producing Four Ears.

Total number of four-ear stalks	75	
Total number of ears	300	
Total weight of ears	688	oz.
Average weight of individual ears	2.29	oz.
Average weight of ears per stalk	9.17	oz.

Plants Producing Five Ears.

Total number of five-ear stalks	42	
Total number of ears	210	
Total weight of ears	526	oz.
Average weight of individual ears	2.50	oz.
Average weight of ears per stalk	12.52	oz.

Plants Producing Six Ears.

Total number of six-ear stalks	15	
Total number of ears	90	
Total weight of ears	164	oz.
Average weight of individual ears	1.82	oz.
Average weight of ears per stalk	10.93	oz.

Plants Producing Seven Ears.

Total number of seven-ear stalks	8	
Total number of ears	56	
Total weight of ears	136	oz.
Average weight of individual ears	2.42	oz.
Average weight of ears per stalk	7.00	oz.

Plants Producing Eight Ears.

Total number of eight-ear stalks	3
Total number of ears	24
Total weight of ears	25 oz.*
Average weight of individual ears	1.04 oz.
Average weight of ears per stalk	8.33 oz.

In making such a count it is not easy to determine what should be considered an ear. In this case anything which carried a single perfect kernel was called an ear, since that seemed to be the most logical dividing line. It follows, therefore, that the numbers here given do not mean well-developed ears, and can not be taken as a guide to the value of a sweet corn for market purposes.

This line of selection, whereby the number of ears is increased, seems to promise more for the grower of silage corn than for the market gardener, who grows sweet corn to market on the ear. A glance at figures 1 and 2 will show that the increase in number of ears is due to the production of ear-bearing suckers to a greater extent than to an increase of ears on the main stalk. In the production of silage corn this type of growth has much more to commend it than in the production of ear corn. In that case the real point at issue, so far as grain is concerned, is whether such a stalk produces a larger weight of kernels than does an ordinary one carrying one or two ears. Our experiments with sweet corn do not answer this question. The corn was not sufficiently ripened in 1903 to permit of its being cured and shelled. The weights given show the weight of corn and cob after husking, but it is obvious that in poorly developed ears, such as many of these were, the proportion of cob to corn would be large, and especially so when the corn was not well ripened and had to be weighed in a comparatively green state. The weight of corn from eight-ear stalks is not comparable with that of the others, since these ears remained on the stalk in a dry room all winter, and were weighed when photographed and husked, just before planting in the spring of 1904.

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* Weighed later, when thoroughly cured.

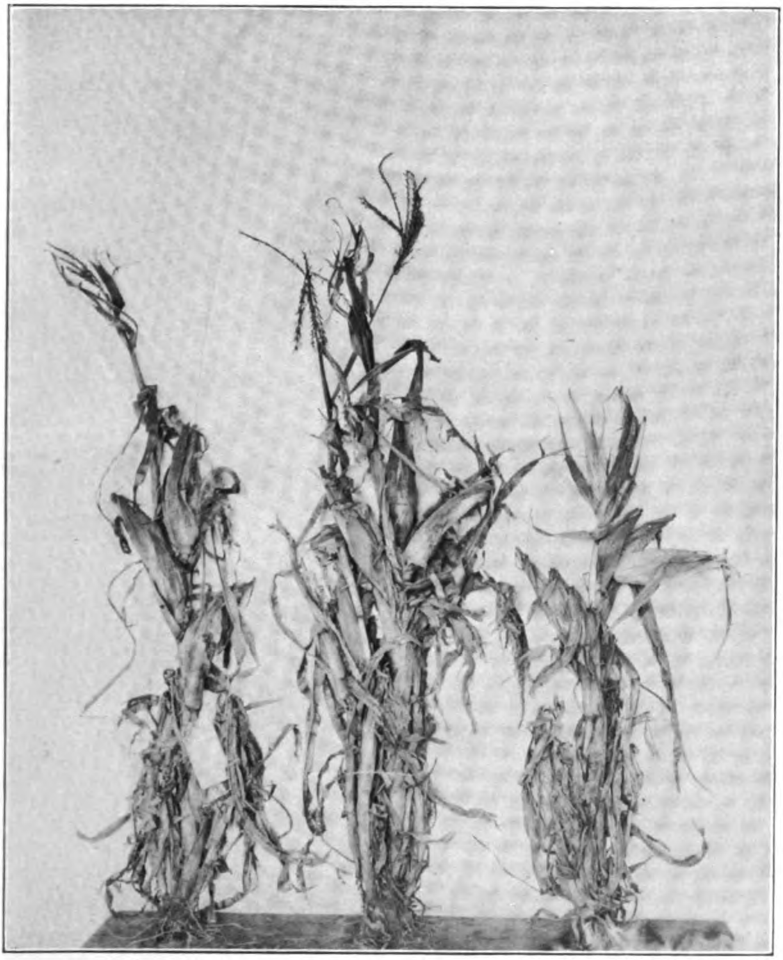

Fig. 1.
Stalks from upper ear selection in 1903.

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Fig. 2.

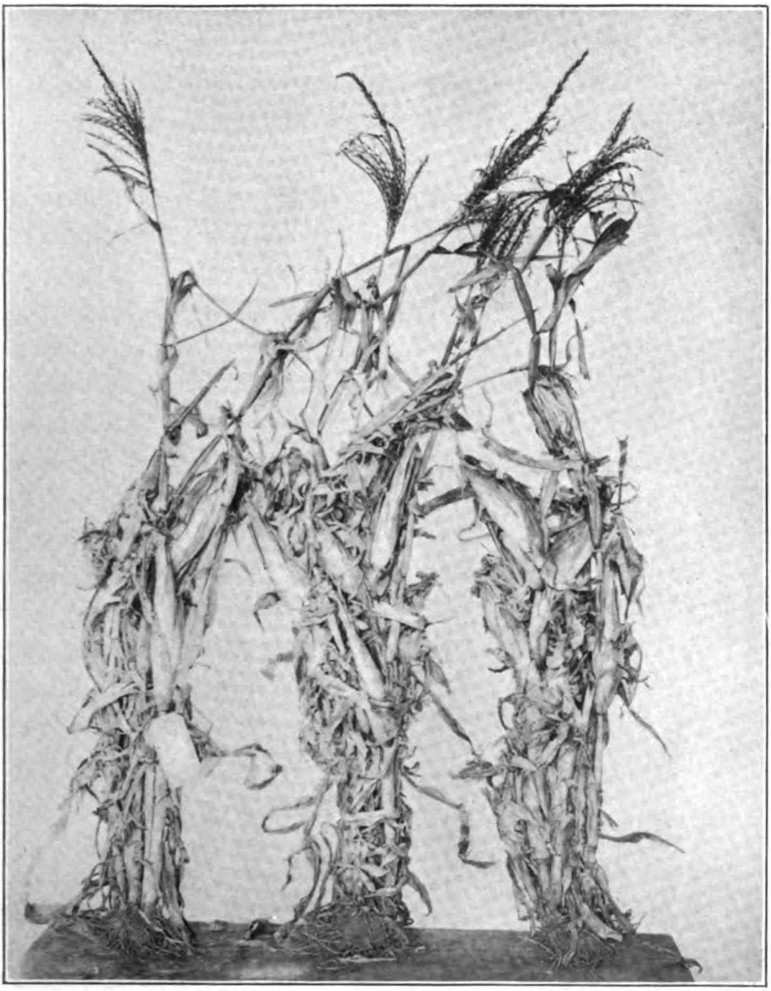

Fig. 2.
Stalks from lower ear selection in 1903.

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In answer to the primary question, which it was sought to answer, the results are apparently conclusive and in strict accord with those of previous years. It will be seen that the average number of ears per stalk produced in the plot where the selection has been continued from the lower ear was 1.38. The average number of ears per stalk where selection has gone on from the upper ear was 2.76, just twice that of the other plot. This is doubless largely attributable to the lack of vigor of seed chosen from these lower ears.

The results are in harmony with the general law, which seems to prevail throughout the plant world, that it is the characteristics of the parent which produced the seed that are likely to be perpetuated, rather than the characteristics indicated by position or type of the individual seed itself. A small potato from a productive hill affords more desirable seed than a large potato from an unproductive hill. Seed from a late garden tomato produced by a plant which ripened the majoirty of its fruits early is likely to produce earlier bearing plants than seed taken from an earlier ripened fruit from a plant which ripens most of its fruit late. So with corn, the character of the plant from which the seed came is of much more importance than the point on that plant from which it came. Since this question has been answered to our satisfaction in reference to sweet corn, the selection from lower ears has been abandoned, and henceforth the plan will be simply to select the best seed from stalks which bear the largest number of ears.

TENT COVERING FOR VEGETABLES AND STRAWBERRIES.

The alleged success of tobacco growers in producing a superior quality of leaf under tents has led to the inquiry whether a similar covering might not prove of value to other plants. Experiments to test this with several kinds of vegetables, and with strawberries, were made in 1903.

The same kind of cloth was obtained as that used for the tobacco work, it being a thin cotton fabric, similar to cheese-cloth. Three tents were erected. One was placed over strawberries. This tent was covered on the top and on the south and west sides, leaving the north and east sides open except for one breadth at the top. The cloth was put on this tent June 3d, just as the berries were beginning to turn. The weather proved unfavorable for such a test, for a great deal of rain and cloudy weather followed, causing a large amount of rot in all the strawberries. There was too little sunshine, even for those in the open field; consequently the results were unfavorable, rather than otherwise, so far as any were observed, but the effect was very slight at most. Later in the season the plants underneath the tent seemed a little more free from disease than those outside, but were apparently no more vigorous, and weeds were a little more troublesome. Under other conditions, with hot, dry weather at picking-time, the tent might prove of value.

A tent open on all sides, having merely a top-cover and a single breadth of cloth on the sides, near the top, was used for cucumbers, in comparison with similar plants in the open ground. Inside the tent twenty-two vines, in seven hills, survived the battle with bugs, and reached bearing size. Outside the tent twenty-nine plants, in seven hills, survived. Thirteen fruits, weighing altogether two pounds one and one-half ounces, were harvested on vines inside the tent. Twenty-six fruits, weighing nine pounds two and three-eighths ounces, were harvested from the outside vines. The tent covering seemed to prove of no value in warding off beetles or mildew; in

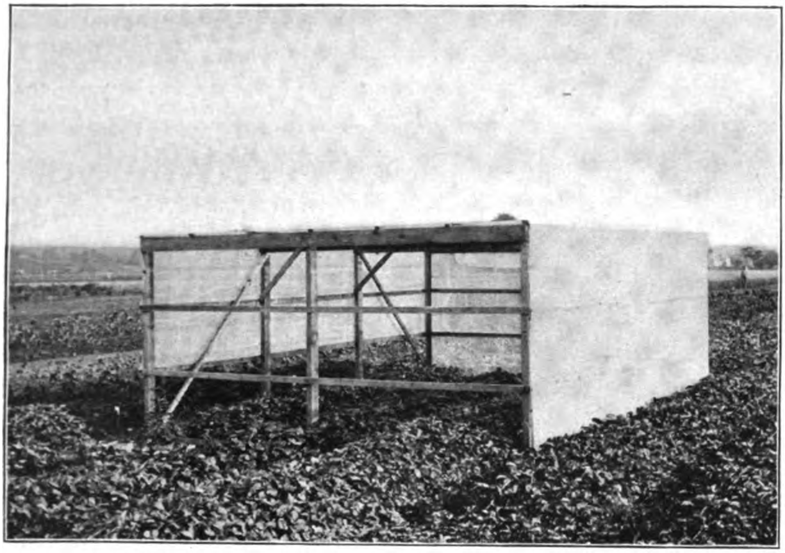

FIG. 1.—Strawberry Tent.

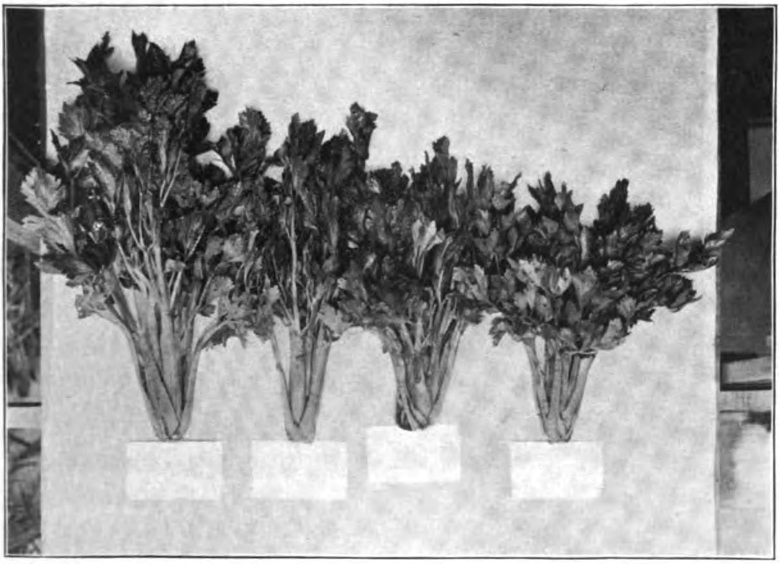

FIG. 4.—Celery from shading experiment.

1. From closed tent.
2. From open tent.
3. From outside, north section.
4. From outside, south section.

fact the shaded plants seemed to be even more badly diseased than those in the open. It was felt that with cucumbers the tent must be left open to permit of the blossoms being pollinated by insects.

In the experiment with lettuce, celery, and cauliflower, a long tent was used, divided into two sections. The south section was entirely closed (Fig. 2). The north section was left open on the north and east sides (Fig. 1). The rows of vegetables extended through each of these sections, and continued for an equal distance in the open ground. Part of the celery plants were set June 8th and the remainder about three weeks later. In this later setting plants obtained from a distance were used, but they made very little growth and gave no results. As the season progressed it was observed that the celery under the tent appeared better than that outside. It was lighter in color, more upright in growth, and the stalks were decidedly longer.

The celery which developed was harvested November 7th and placed under a greenhouse bench until November 10th, when the plants were measured and weighed. The results are as follows, for equal distances of row:

Outside, south section	11 lbs. 8 oz.
Outside, north section	14 lbs. 12½ oz.
Average	13 lbs. 2¼ oz.

These two sections correspond in length to the closed and open sections of the tent.

In the open tent	10 lbs. 6½ oz.
In the closed tent	14 lbs.

After weighing with the roots on, the plants were cleaned, trimmed to marketable shape and weighed again, with the following results:

Outside, south section	7 lbs. 12 oz.
Outside, north section	9 lbs 3½ oz.
Average	8 lbs. 7¾ oz.
Open tent	7 lbs. 5 oz.
Closed tent	11 lbs.

In the first weighing it was observed that slightly more earth clung to the roots and leaves taken from the plants outside, which would tend to make their weight slightly excessive. The average length of stalk, in inches, under the three conditions was as follows:

Outside	4.09
Open tent	5.11
Closed tent	6.03

In other words, the celery from the open tent averaged 25 per cent. taller than that grown in the open ground, and that from the closed tent averaged 40 per cent. taller. (See Fig. 3.) The celery from the closed tent was better in other ways; not only were the stalks longer, but the color was better, being more nearly blanched, and there was less waste material in the shape of roots and leaves. Plants outside of the tents suffered much more from early frost than did those inside.

The flavor of the celery from the closed tent was much superior to that outside. That from the open tent seemed to differ but little from that grown outside. In the matter of tenderness, very little difference was to be observed. The celery grown inside the closed tent seemed slightly more stringy than that grown outside. It is possible that the better flavor of that grown inside may have been due in part to its having been more completely blanched.

With cauliflower, the influence of the tents appeared to be less marked. Those under the open tent were badly injured by worms. Under the closed tent the injury was not serious. The shade had a retarding effect upon the heading, those plants under the tents being later in maturing than the ones grown outside. Several of the outside plants were killed by the root-maggot.

Four varieties of lettuce were used. Improved Salamander, Market-Gardener's Private Stock, American Gathering, and Mammoth Black-seeded Butter. Part of these were grown from seed in the different positions, and part were from transplanted plants. During the early part of the season the lettuce underneath the tents seemed

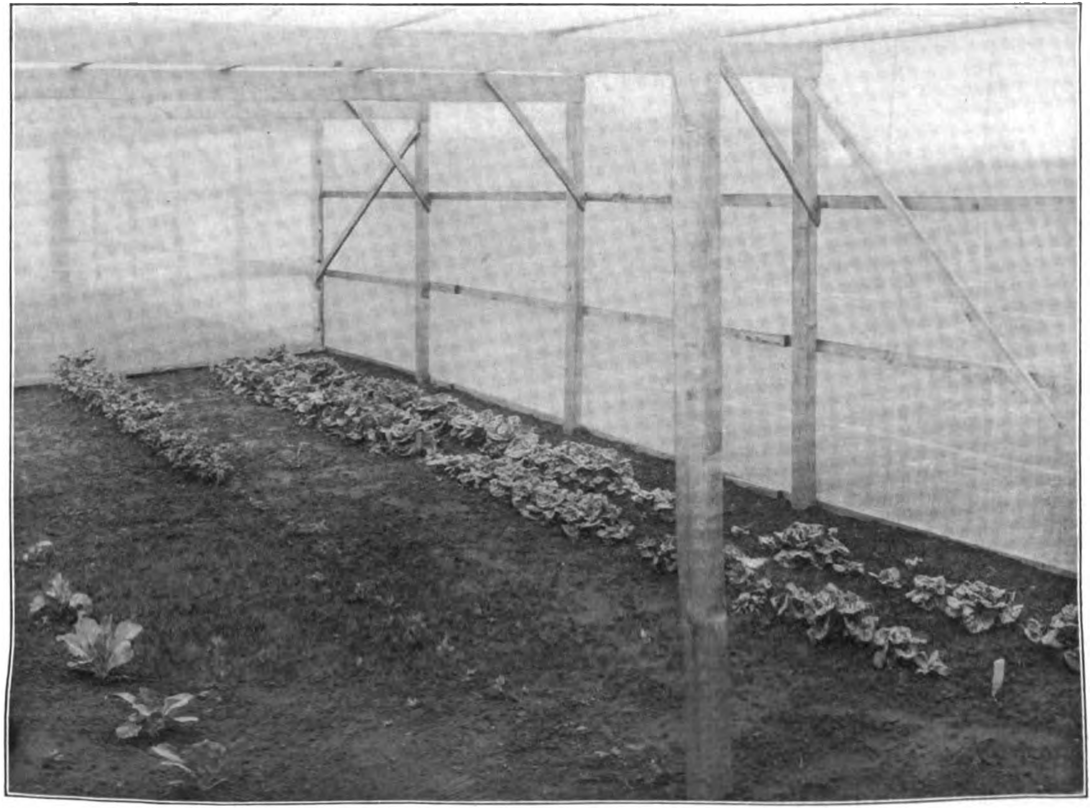

Fig. 2.
Vegetables under tent open on two sides.

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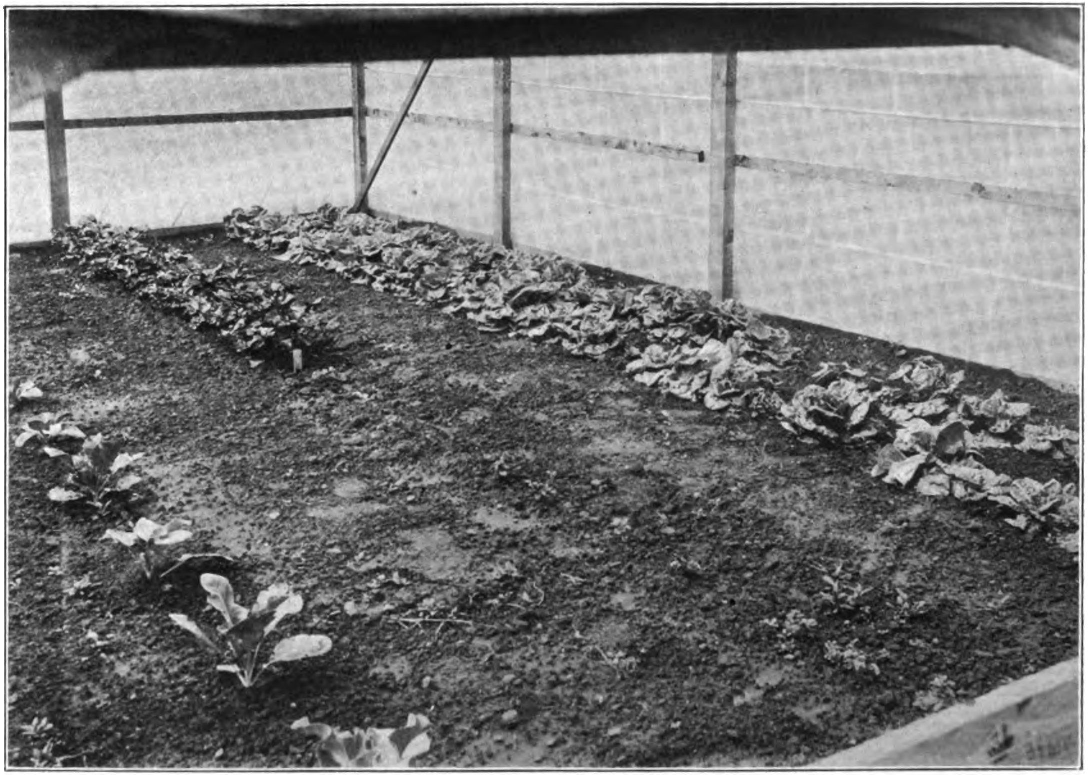

Fig. 3.
Vegetables under closed tent.

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to be doing much better than that outside, but by the middle of August conditions were apparently reversed and the outside lettuce appeared to be doing better. The tent appeared to give a decided advantage to transplanted lettuce. The plants started off more promptly and fewer had to be replaced. That in the closed tent appeared to do a trifle better than in the open. A note made August 20th states that lettuce inside the tent was apparently not heading as well as that outside, but the leaves appeared to be more tender and delicate. Owing to an error made by one of the workmen in sowing seed, and to another made in transcribing records, it is impossible to give full comparisons of yields under the different conditions; but so far as they are available they show a much heavier yield from plants grown in the open ground than from those grown under the tents. In one of the open sections Improved Salamander, grown from seed, yielded 63½ ounces, while in the open tent it yielded 34 ounces and in the closed tent only 10¼ ounces. This was an extreme case. The same variety, transplanted, gave an average yield of 52¼ ounces from the open ground, a yield of 47 ounces from the open tent, and 32¼ ounces from the closed tent. Market Gardener's Private Stock gave an average of 50⅞ ounces on the open ground, 34¼ ounces from the open tent, and 12 ounces from the closed tent.

The experiments are being continued in 1904 with lettuce, cauliflower, and celery.

DIVISION OF ANIMAL HUSBANDRY.

In the absence of a report from the head of this division, readers are referred to the report of the Director, pages 173 to 178, for a brief account of the work which has been in progress during the year.

DIVISIONS OF AGRONOMY AND CHEMISTRY.

MAGNESIUM AS A MANURE.

H. J. WHEELER AND B. L. HARTWELL.[1]

With the advent of ready-mixed commercial fertilizers and the frequent reference to the so-called "essential elements," there has apparently been a tendency in this country, on the part of both the agricultural press and of agricultural investigators, to ignore or forget the possibility that other elements than potassium, phosphorus, and nitrogen should frequently be applied to soils either for their manurial, physical, or chemical effect; hence it is not surprising that little should have been heard concerning magnesium. It is not the intention to enter, at this time, upon a detailed discussion of all of the phases of the magnesium question, but rather to call attention to a few points, and to give certain data relating to the matter, which have been obtained at this Station.

E. Wolff[2] in 1851 found that magnesia was helpful to plants, though its influence was not great. Later, Mulder,[3] in commenting upon the results, remarked that the whole question depended upon the soil; and the question is "What is substituted?" From this it would appear that Mulder did not consider magnesium in and of itself an essential element of plant food, without which plants could not reach full maturity when supplied with all of the other elements which are required. He also calls attention to the fact that Tennant found burned dolomite (a carbonate of lime and magnesia) injurious to vegetation.[1] This was explained by Davy as due to the fact that magnesia remains caustic longer than lime. He did not, nevertheless, consider the question of the injurious action of magnesia as having been sufficiently studied then to enable one to speak positively concerning it.

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[1] The authors are indebted to N. L. C. Moore and J. B. Spears for the care of the details of the pot experiments.

[2] Erdmann's Jour. (1851), 51, p. 15.

[3] Die Chemie der Ackerkrume; Berlin (1863), vol. 3, p. 77

Schmiedenberg[2] claimed an important function for magnesium in the formation of the albuminoids. Likewise, E. von Raumer[3] ascribed to magnesia the important function of aiding in the translocation of starch within the plant, beginning with the place of its formation.

According to A. B. Griffiths,[4] "M. Ville found in his experiments that when magnesia was excluded from a soil the yield of wheat fell from 337 to 123 grains."

Bretfeld[5] speaks in no uncertain terms of the importance of magnesium as a plant food; for he asserts that an increase in the dry weight of plants cannot take place in its absence.

O. Loew[6] has called attention to the fact that magnesium which is now accepted as essential to plant growth is nevertheless sometimes poisonous in its action. The theoretical features of the matter are discussed in detail, and he advances a theory upon which he believes the conflicting reports about its action may be satisfactorily explained. In fact, he advances the idea that the poisonous action of magnesia which is sometimes observed may be overcome by applying sufficient lime.

Loew[7] mentions that in certain seeds there are one hundred molecules of magnesia to seventeen of lime, and in the leaves there are two hundred and twenty-four of lime to one hundred of magnesia.

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[1] Ibid, pp. 69–70.

[2] Zts. f. Physiolog. Chemie 1 (1877), p. 205.

[3] Die Landw. Vers. Sta. 29 (1883), p. 279.

[4] A Treatise on Manures, London (1889), p. 24.

[5] Pflanzenphysiologie. Berlin (1884), p. 135.

[6] Die Landw. Vers. Sta., 41 (1892), pp. 466–475. See also Flora (1892), pp. 368–394.

[7] Ibid, p. 473.

S. W. Johnson[1] points out the fact that in tobacco leaves and stalks nearly one-third as much magnesium as calcium is removed from the soil.

In a series of experiments with lime and magnesia, Atterberg[2] found that the compounds of magnesia with humus were more soluble than those of lime with humus. Thinking for this reason that there might be some advantage on peat soils in employing magnesian lime instead of ordinary lime, he conducted a number of experiments in which varying amounts of lime and magnesia were employed. The best result was obtained with a given amount of magnesia, and still greater applications proved harmful in a much greater degree than excessive amounts of lime. Subsequent trials showed that the injurious results following the use of the larger amounts of magnesia were entirely overcome by the employment of lime with it in the proportions existing in magnesian lime, prepared from dolomite. Special value of magnesian lime as compared with ordinary lime is reported by D. Meyer[3] in connection with certain leguminous plants.

According to Stutzer,[4] soils usually contain enough magnesia to meet the requirements of plants.

Dassonville[5] experimented with lupines and found that magnesium sulfate (Epsom salts) seemed to retard the development at first, but that later it became indispensable.

A. Larbalétrier and L. Malpeaux[6] speak of the fact that in the Department of Pas-de-Calais, France, magnesium sulfate has been used as a manure for beets for some years with distinct advantage.

In experiments by Passarini[7] it was found that the yield of wheat was reduced by the use of magnesium carbonate at the rate of 440 and 1,100 pounds per 2.47 acres.

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[1] Conn. State Station Report, 1892, p. 24. Abs. E. S. R. 4, p. 910.

[2] Svenska Mosskultur-föreningens tidskrift 1891, pp. 121–122, abs. in Centralbl. f. Agrikultur-Chemie, 21 (1882), pp. 298–299.

[3] Landw. Jahrbücher 29 (1900), p. 961.

[4] Leitfaden der Düngerlehre, Leipsig, 1893, p. 16.

[5] Revue générale de Botanique 8 (1896), p. 331, abs. Jahresb. f. Agrikultur-Chemie, 1896, p. 260.

[6] Annales Agronomiques 22 (1896), p. 31.

[7] Bol. Scuola. Agr. 3 (1895), pp. 140–142, abs. Jour. Chem. Soc., London, 72 (1897), No. 142, II, p. 587.

Strasburger, Noll, Schenck, and Schimper[1] state that magnesium, like potassium, participates in the most important synthetic processes of plants. A Mayer[2] asserts that so far as experiments with the higher plants have thus far shown, they all fully confirm the fact that magnesium is absolutely essential to them. Mayer also called attention earlier to the apparent close relation of magnesia and the proteids of plants. Loew,[3] referring to the belief expressed by Raumer that magnesia was of prime importance from a physiological standpoint in aiding directly in the movement of starch, is of the belief that it is of importance only remotely in this connection, and that its prime physiologic function is in connection with the formation of the nitrogenous bodies in plants.

After making an examination of several Florida soils, Persons[4] arrives at the conclusion that many of them are apparently deficient in magnesium.

Few recent writers upon agricultural matters have treated the subject of magnesia in a general way with more thoroughness than Storer.[5] He begins his discussion with the assertion that "Magnesium is one of the elements absolutely necessary for the growth of plants." Later he calls attention to the fact that the ash of wheat-grain contains 12 per cent. of magnesia and but 3 per cent. of lime, and in the ash of peas the relation is eight of magnesia to four of lime. Storer cites experiments by Stöckhardt upon certain low lands in Saxony in which magnesium in magnesian limestone proved helpful to plants. He also calls attention to the possibility of its action as an indirect manure.

Referring to the report by Tennant of the poisonous action of caustic magnesia, he proceeds to cite instances recorded by Davy where the same "magnesian limestones were used with good effect in field culture." Storer also cites Davy as authority for the statement that in "one of the most fertile tracts in Cornwall, the Lizard, the soil contains much magnesia," and he adds that according to Schuebler "the soils of several of the most fertile districts in Wurtemberg are derived from magnesian limestones and contain more or less carbonate of magnesia." Storer calls attention to the statement by Knop that the ill effects sometimes resulting in field-culture from the use of magnesia may probably be overcome by the use of a liberal amount of lime, a point since apparently substantiated by the work of Loew.

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[1] A Text Book of Botany, translated by Porter, N. Y. and London (1898), p. 173.

[2] Lehrb. d. Agrikultur-Chemie, Part I, Heidelberg (1895), p. 287.

[3] Bul. 18, U. S. Dept. of Agric., Div. of Veg. Phys. and Path. The Physiological Rôle o Mineral Nutrients.

[4] Bul. 43, Fla. Expt. Sta., p. 655.

[5] Agriculture in some of its Relations with Chemistry, New York (1897), vol. 2, pp. 516–521

EXPERIMENTS WITH MAGNESIA AT THIS STATION.

The possibility of a lack of magnesia in the soil of the Station and College farm was indicated in a somewhat unusual manner.

In the year 1896 two plots were selected and manured alike with nitrogenous, potassic, and phosphatic manures. Barley, beets, clover, and grass were grown upon each plot in that and in the succeeding year. One plot received air-slaked lime at the rate of about two and one-half tons per acre, the other plot remaining unlimed. It was found that but few clover plants survived upon the unlimed plot, but that a magnificent crop was obtained upon the plot that had been limed. Common sorrel (*Rumex acetosella*), on the contrary, was found to thrive splendidly upon the unlimed plot, while upon the one which was limed it was nearly absent. At that time an effort was made to learn if the lime had acted beneficially by virtue of serving as a direct plant food, or by reason of its improving the physical or chemical character of the soil. It was assumed, if it had been so greatly needed for its direct food effect, that the clover grown upon the limed plot would contain in its completely dry condition a greater percentage of lime than the clover plants which grew upon the unlimed soil. Accordingly the clover, as well as the sorrel, from both plots was analyzed. Below are given the results obtained:

Percentages in Dry Matter.

	COMMON RED CLOVER.		COMMON SORREL.	
	Limed.	Unlimed.	Limed.	Unlimed.
Calcium oxid (lime)	2.104	2.242	0.940	0.965
Magnesium oxid (magnesia)	0.861	0.295	0.858	0.329
Sodium oxid (soda)	0.138	0.130	0.451	0.360
Potassium oxid (potash)	2.528	3.314	3.075	2.387
Phosphoric acid (P_2O_5)	0.574	0.574	0.715	0.791
Sulfuric acid (SO_3)	0.372	0.373	0.412	0.360

The results showed, as will be observed, that the percentage of lime was smaller in both instances in the plants grown upon the limed plot than in the others, but that in the case of the clover the percentage of magnesia had increased about 2.9 times, and in the common sorrel about 2.7 times, where lime was applied.

Even though it was fully recognized that plants may take up much more of certain plant foods than are really required, the fact of there being such a striking increase in the per cent. of magnesia and no increase in the per cent. of lime in the plants grown upon the limed plots aroused a suspicion that a deficiency of magnesia might exist. It was not known positively what percentage of magnesia was present in the lime which had been employed, though other lots from the same source contained about three per cent. of magnesia. In fact it was immaterial to the inquiry, which was suggested by the results, whether the magnesia was associated with the lime which was applied or whether it was liberated from the soil by the action of the lime. In order to throw light, if possible, upon the question whether the particular soil was really deficient in readily assimilable magnesia, two experiments with soil from the unlimed plot were begun in the year 1898. One experiment was conducted in four ordinary, cylindrical, galvanized iron pots, eight inches in diameter and sixteen inches deep, with a perforation at the bottom to permit of drainage and ventilation. The eight pots used in the other case were the regular cylindrical "Wagner" pots, eight inches in diameter and eight inches deep. This pot has a tube passing down the outside and entering it through the side just at the bottom. This side tube serves alike for the introduction of water and for ventilation.

The manurial substances employed in each pot were as follows:

	Grams.
Sodium nitrate, c. p.	5.000
Potassium phosphate, c. p.	3.000
Calcium carbonate, c. p.	15.942

Two of the tall pots and four of the Wagner pots received, each, in addition, four grams of c. p. hydrous magnesium sulfate.

Barley was planted, and, after thinning, twenty-seven plants remained in each pot. The weight of moist soil, containing 27.73 per cent. of water, was twenty-four pounds per pot for the tall pots and fourteen pounds for the smaller ones.

Barley was selected for this experiment in preference to some other cereal, for the reason that analyses of it frequently show a greater percentage of magnesia than certain other of the related plants.

The water capacity of the soil was determined so as to insure that proper water percentages would be maintained from day to day.

The barley was harvested July 22. The soil in each of the pots was then removed, again thoroughly mixed and returned to the pot from which it came, and golden millet seed was sown August 12.

The plants were subsequently thinned to twenty-eight per pot. This second crop was harvested November 11.

Below are given the weights, in grams, of the crop from each pot, after drying artificially in the laboratory to practically constant weight:

BARLEY.				GOLDEN MILLET.			
Pot No.	With Magnesium Sulfate.	Pot No.	Without Magnesium Sulfate.	Pot No.	With Magnesium Sulfate.	Pot No.	Without Magnesium Sulfate.
1*....	14.90	3*....	14.57	1*....	13.37	3*...	2.38†
2*....	16.11	4*....	16.17	2*....	13.88	4*...	2.60†
92.....	10.31	96.....	11.36	92.....	13.95	96....	12.00
93.....	9.23	97.....	10.56	93.....	13.61	97....	13.52
94.....	9.34	98.....	10.25	94.....	12.75	98....	13.68
95.....	10.12	99.....	10.80	95.....	13.17	99....	13.00
Average weight of crop per pot,	11.67	....	12.28	....	13.46	......	13.05

From the foregoing results it will be seen that so far as the averages show there was slight injury to barley, rather than benefit, from the use of the magnesium salt. As concerns golden millet, the reverse was true. The poor results with golden millet in pots Nos. 3 and 4 are extremely striking, and seem to admit of no satisfactory explanation. It could not have been possible that some one or more of the manures was omitted by accident, for otherwise the first crop would have indicated the fact; and furthermore the check method employed in making the weighings should have precluded such a possibility.

Taken as a whole, these results fail to give satisfactory and positive evidence of a lack of magnesia in this soil.

In 1899 a new lot of soil was taken from the same plot as that employed in 1898. Each pot in the experiment received 5 grams of c. p. sodium nitrate and 3 grams of c. p. potassium phosphate. The deep pots Nos. 1 and 2 and the Wagner pots Nos. 92, 93, 94, and 95 each received in addition 4 grams of c. p. hydrous magnesium sulfate. Oats were grown, forty plants having been left in each pot.

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* Pots Nos. 1 to 4, inclusive, were of the deep pattern, and pots 92–99, inclusive, were the more shallow Wagner pots.

† Omitted from the average.

Owing to the fact that the oats were badly affected with rust, they were cut just before the unfolding of the head. The average height of the oats in each pot was determined. The oat plants were then harvested, dried first at room temperature, and finally to practically constant weight in a drying oven. The heights of the individual plants were very variable in all of the pots, and in pots Nos. 2, 3, 93, 94, 97, and 99 there were several short and very slender stalks.

Below are given the average heights of the stalks, in centimeters, and the yields of material in grams, after artificial drying:

Pot No.	WITH MAGNESIUM SULFATE.		Pot No.	WITHOUT MAGNESIUM SULFATE	
	Average Height of Plants in Ctm.	Weight of Fully-dried Plants, Grms.		Average Height of Plants in Ctm.	Weight of Fully-dried Plants, Grms.
1*...........	43	23.74	3*...........	55	24.11
2*...........	44	23.18	4*...........	56	26.19
92............	41	22.52	96............	42	24.60
93............	46	23.01	97............	45	22.32
94............	42	21.69	98............	43	25.08
95............	44	22.66	99............	46	22.35
Average weight	....	22.80	....	....	24.11

* Deep pots.

From the foregoing it will be seen that both the average height of the stalks and the average weight of produce were less where magnesium sulfate was applied than where it was omitted, which fact, taken in conjunction with the results of the preceding year, fails to give positive evidence of a lack of magnesia in the particular soil under consideration, at least so far as concerns the three kinds of plants which were employed in the experiment.

EXPERIMENTS WITH KINGSTON-PLAIN SOIL.

In the experiment in 1898 with soil from Kingston Plain galvanized iron ash cans 18 inches in diameter and about 26 inches deep were employed as pots. The bottoms of the pots sloped gradually to the center, at which point openings were left for purposes of ventilation and drainage. The cans were set about 18 inches apart in trenches, in the center of which were laid ordinary drain tile to prevent the rising of water from the surrounding soil. The spaces between the pots were then filled with soil so as to insure in so far as possible a normal temperature. A small amount of broken granite was placed in the bottom of each pot, after which 110 pounds of well-mixed sub-soil from the "Plain" were added. This was followed by 123 pounds of surface soil from the permanent experimental plots Nos. 74, 76, 77, 78, 79, and 80, which had been devoted to Indian corn for several years without manures. The pots projected about two inches above the surrounding soil, so that the level of the soil within and without the pots was uniform.

Each pot was manured as follows, viz.:

Grms.	
20	c. p. sodium nitrate.
12	c. p. potassium phosphate.
110	c. p. calcium carbonate.

The manures were distributed over the surface of the pots and were worked into the soil with a spade to a depth of from six to eight inches. Pots Nos. 56, 70, and 84 each received in addition 16 grams of c. p. hydrous magnesium sulfate. Like numbers of grains of barley were planted in each pot, and the plants were thinned, as soon as possible, to 150 per pot. The plants were harvested when the barley was in the "milk," for the reason that it was practically impossible at that time to protect them from birds if left to ripen their seed, and the pots had not then been protected by a wire netting.

Even very early in the season it was apparent that the growth was decidedly better where magnesium sulfate was applied than where it was omitted. Below are given the weights of the crop dried at 100° C; the percentages of magnesia (magnesium oxid), and of lime (calcium oxid) which were found in the dry matter of the plants, and the total amounts of these constituents removed by the plants from each pot.

These data are as follows:

	Pot No.	Entire crop of Barley dried at 100° C. (grms.)	Per Cent. in Dry Matter.		Amount Removed by the Crop (grms).	
			Magnesia (Magnesium oxid).[*]	Lime (Calcium oxid).[*]	Magnesia (Magnesium oxid).[*]	Lime (Calcium oxid).[*]
With magnesium sulfate...	56	52.07	0.34	0.48	0.177	0.250
	70	48.86	0.36	0.36	0.176	0.176
	84	50.04	0.30	0.45	0.150	0.225
Without magnesium sulfate.	14	37.11	0.15	†	0.056	†
	28	45.31	0.14	0.49	0.063	0.222
	42	39.48	0.17	0.34	0.067	0.134

[*] The authors are indebted to Dr. Martha Austin for these determinations.

† Not determined.

It will be observed from the foregoing figures that the application of magnesium sulfate resulted in material and unmistakable advantage in this instance, the average yield without magnesium having been 40.63 grams per pot, and with magnesium 50.32 grams. It is of interest to note that the percentage of magnesia in the dry matter of the barley plants was nearly twice as great where the magnesium salt was used as where it was omitted. The percentages of lime in the dry matter of the plants were not materially influenced by the application of the magnesium salt, yet it will be observed that where the percentage of lime is low the per cent. of magnesia is frequently higher, and *vice versa*.

RESULTS IN 1899.

The experiment was continued in the same pots and soil the succeeding year, with the substitution of oats for barley.

Each pot was again manured with 12 grams c. p. potassium phosphate and 20 grams of c. p. sodium nitrate. Pots Nos. 56, 70, and 84 each received, as in the previous year, 16 grams of c. p. hydrous magnesium sulfate. After the oats came up they were thinned to 200 plants per pot. The plants were badly attacked by rust, and were cut just as the heads were appearing.

Below is given the weight of the entire crop from each pot, the per cent. of magnesia in the dry matter, and the actual amount of magnesia removed by the crop:

	Pot No.	Weight of entire crop dried at 100° C. (grms.)	Per cent. of Magnesia (Magnesium oxid) in dry matter.*	Amount of Magnesia (Magnesium oxid) removed by the crop.
With magnesium sulfate.......	56	43.60	0.41	0.179
	70	46.71	0.42	0.192
	84	47.57	0.39	0.186
Without magnesium sulfate....	14	42.22	0.21	0.088
	28	41.95	0.22	0.092
	42	45.19	0.22	0.099

It will be observed that the results with oats are in agreement with those secured with barley in the previous year, both as concerns the increase in yield due to the employment of magnesium sulfate and as concerns the relative percentages of magnesia found in the dry matter of the plants produced. The average yield where magnesium sulfate was not used amounted to 43.12 grams per pot, and where the magnesium salt was applied it amounted to 45.96 grams.

By the employment of magnesium sulfate the percentage of magnesia in the crop was almost doubled, just as in the case of barley the year before. In view of the quite similar increase in the percentage of magnesia in the crop which resulted from the application of magnesium sulfate, it is of interest to note that the additional yield of dried material in the case of the barley was much greater than in the case of the oats. From these results it appears that after furnishing a liberal amount of lime and all three of the so-called "essential" elements, phosphorus, potassium, and nitrogen, the additional application of magnesia raised the crop of oats 6.59 per cent., and of barley 9.69 per cent. In view of this result it is of interest to see if indications have been afforded, in other experiments, of a deficiency of magnesia in our soil.

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* The authors are indebted to Dr. Martha Austin for these determinations.

OTHER OBSERVATIONS AT THIS STATION INDICATING A LACK OF MAGNESIA.

In another experiment, conducted in 1898 with soil and pots identical with those described on page 230, each pot was manured with the following materials, viz.:

20 grams nitrate of soda.
30 grams acid phosphate.
10 grams muriate of potash.

In this experiment no lime was applied. Three of the six pots received 19.16 grams of c. p. hydrous magnesium chlorid per pot. Like amounts of barley seed were sown in each instance, and subsequently the plants were thinned to an equal number per pot.

The yields of air-dried plants were as follows:

With Magnesium Chlorid.		Without Magnesium Chlorid.	
Pot No.	(grms.)	Pot No.	(grms.)
53	47.30	10	43.95
54	53.68	24	38.56
55	38.44	38	48.55

Owing to the variation in the individual yields in each series, no positive proof of a lack of magnesium is afforded, yet the results indicate the possibility of an advantage from the use of magnesium chlorid.

The next year each pot was manured in exactly the same manner as before, but in this instance the yields of spring rye from the pots Nos. 10, 24, and 38 without the magnesium salt were 2.97 3.45, and 4.52 grams, respectively, and the yields from pots Nos. 53, 54, and 55 which received magnesium chlorid were respectively 48.85, 50.90, and 54.22 grams.

If the poor yield in the pots without the magnesium chlorid was due to acidity, it is not readily undertsood how the magnesium chlorid could have overcome the condition.[1] It is possible that a breaking up of certain salts resulted in the one instance which gave rise to ions that were particularly noxious to the plants, a condition which was possibly prevented in some way by the magnesium salt. Owing to the complexity of the possible chemical reactions taking place in soil solutions, the exact nature of such changes can not be predicted with certainty.

The third year the nitrate of soda, acid phosphate, and muriate of potash, which had been applied previously to each pot, were replaced by the following materials, viz.:

30 grams basic slag meal,
30 grams dried blood,
20 grams potassium-magnesium carbonate.

As a result of this application the three pots which had received previously no magnesia (Nos. 10, 24, and 38) gave yields of oats amounting to 93.17, 89.42, and 83.50 grams, respectively, while the corresponding crops from the three pots manured previously with the magnesium salt were 82.22, 85.21, and 85.74 grams, respectively. In brief, the average yield where the magnesium chlorid had been used amounted per pot to 84.39 grams, and where the new mixture of manures[2] was used without magnesium chlorid the average yield was 88.68 grams. This result, showing such a splendid growth in the three pots where the crop was so nearly a failure the previous year, can not be satisfactorily accounted for upon the supposition that the poor result the preceding season was due wholly or chiefly to a lack of magnesia as a plant food, but that the mixture of basic slag meal, dried blood, and potassium-magnesium carbonate had prevented the unfavorable dissociations of salts which had perhaps resulted when nitrate of soda, acid phosphate, and muriate of potash were employed. The greater yield in the last year of the test, in the pots where the magnesium salts had been omitted during each of the two preceding years, might be explained upon the assumption that the proportion of magnesia to lime in the series of pots receiving magnesium chlorid had now become too great. Fortunately two other pots had received identically the same manures in each year, including the magnesium chlorid, and, to each of these, caustic magnesia had been added the first season at the rate of 44 grams per pot, it having been omitted in each of the subsequent years. The yields of oats per pot in these two instances were 86.72 and 89.11 grams, respectively, giving an average of 87.93 grams as compared with an average of 84.39 grams where the magnesium chlorid was used without the further addition of caustic magnesia. These results are, therefore, sufficient to show that the magnesium had been positively beneficial, probably in consequence of its preventing unfavorable dissociations, and possibly by virtue of its having acted to a limited extent as a direct manure.

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[1] It is interesting to note that aqueous solutions of the c. p. (so-called) hydrous salts, magnesium chlorid, and magnesium sulfate, reacted alkaline with litmus and acid with phenolphthaleïn. Stcherbakaff found the same to be true of *carefully purified* magnesium sulfate.

[2] It will be remembered that this new mixture was used in both groups of pots and that it contained magnesium carbonate. That it should correct the unfavorable conditions in the acid soil was to be expected since other basic substances have invariably done the same. The fact that hydrous magnesium chlorid accomplished the same result where other chlorids have not, gives a *single* indication of the efficiency of the magnesium ion in possibly preventing the toxic action of certain compounds which seem to accompany acid soils.

CERTAIN NEGLECTED FACTORS BEARING UPON THE QUESTION OF MAGNESIUM POISONING.

Attention was called on page 225 to the statement which Storer attributes to Knop, to the effect that the injury from magnesia sometimes produced in the field might probably be overcome by the use of a liberal amount of lime. According to Storer,[1] Knop "found that the presence of any salt of magnesia in the solutions employed for experiments in water-culture did manifest harm unless there was also present an abundance of lime, potash, or ammonia salts." According to the same authority, Knop suggested the desirability of using sulfate of potash rather than muriate of potash, in view of the possible formation in some soils of magnesium chlorid, provided the muriate was used. From this it would appear that Knop looked upon magnesium chlorid as *necessarily* a plant poison, a point which is in no wise borne out by our own experiments.

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[1] Agriculture, Vol. II, New York (1897), p. 518.

According to Loew[1] who holds the view "that a calcium protein compound participates in the organized parts of the nucleus and chorophyll body * * * it might be expected that magnesium salts of the stronger acids would exert a noxious action. The lime as a stronger base would in such a case combine with the acid of the magnesium salt, while the magnesia would enter into the place which the lime had occupied in the organized structures, the capacity for imbibition would thereby be altered, and a disturbance of its structure would result which would prove fatal. On the other hand, judging from the laws of the action of masses, it would naturally be inferred that an excess of lime salts would remedy the evil effects by making the reverse process possible."

Loew then proceeds to add that "a detrimental action is observed when plants are treated with sulfate or nitrate of magnesium in the absence of calcium salts." From this statement it might appear that Loew intended to limit his conclusions as to the poisonous action of magnesium salts in the absence of an excess of lime to merely the magnesium sulfate and nitrate, but later he adds,[2] "that magnesium salts can fulfill their nourishing functions only in the presence of calcium salts, while in the absence of calcium salts they even exert an injurious action." This statement relating to the magnesium salts is made without apparent qualification as to its reference exclusively to the sulfate and nitrate, from which it is not clear that the poisonous action was intended to be attributed only to those two salts. Again in his discussion of the ill effect of kainit, observed by Schultz, of Lupitz, and of the statements by Maercker concerning the depression of the sugar and starch content of certain plants caused by spring applications of kainit,[1] all of which he attributes to the magnesium salts, the indictment appears to be brought both against magnesium sulfate and magnesium chlorid.

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[1] Bul. 18, U. S. Dept. of Agr., Div. of Veg. Phys. and Path., Washington (1899), p. 42.

[2] Ibid, p. 47.

Recognizing the fact that agricultural plants cannot thrive without calcium, it may well be a question, in some cases where injury arises in the presence of magnesium salts and in the simultaneous absence of calcium, whether it is to be attributed to the presence of an excess of magnesium salts any more than to an absence of calcium. This is particularly the case, since it is evident that the plants in the absence of calcium must inevitably die. It does not appear that in all cases of alleged magnesium poisoning a positive or an immediate toxic effect is observed which is in all cases distinguishable from the results of mal-nutrition which may arise from a deficiency of any one of the essential elements of plant food. Under such circumstances many cases of supposed magnesium poisoning may readily find a more satisfactory explanation. Unless the toxic effect of magnesium is so striking and positive in its character as to be recognizable under all conditions from mal-nutrition due to other causes, one may with propriety invert the following quotation from Loew to the effect that "a detrimental action is observed when plants are treated with sulfate or nitrate of magnesium in the absence of calcium salts," and say *a detrimental action is observed when plants are treated with sulfate or nitrate of calcium in the absence of magnesium salts.* Indeed no one would be justified in drawing a conclusion, in such a case, that an excess of magnesium salts was a remedy for the toxic action of calcium, nor, indeed, for even assuming that calcium was a poison. In fact it may possibly, at times, be difficult to distinguish between the result of poisoning by magnesia and the injury from undue acidity or alkalinity of the soil, particularly in view of cases where the cessation of growth is not attended by outward phenomena different from those which may accompany other disturbances of the functions of the plant.

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[1] Die Landw. Vers. Sta. 41 (1892), p. 474.

It is of interest to note that Loew[1] would apparently explain all of the injury resulting from kainit as observed by Schultz of Lupitz[2] and other investigators, to a toxic action of the magnesium salts, notwithstanding that it is generally recognized that the spring application of even potassium or sodium chlorid depresses the sugar and starch content of certain plants, and that Schultz of Lupitz has called attention to the tendency of kainit to render his light, sandy soil acid, a condition which must affect materially the growth of certain plants.

May[3] experimented with carbonates of lime and magnesia in varying proportions, employing oats and cowpeas. He says: "The seed germinated first and plants were best beginning with the pots containing the largest amount of lime and the smallest amount of magnesia, and ranging down in thriftiness to those containing the smallest amount of lime and the greatest amount of magnesia."

In every case the total amounts of calcium oxid and magnesium oxid represented, were equivalent to 1.00 per cent. He adds that "Later the best growth of both oats and cowpeas was in the soil containing CaO 0.8 per cent., and MgO 0.2 per cent." Where the calcium oxid was equal to but 0.6 per cent. or less and the magnesium oxid to 0.4 per cent. or more, the plants were sickly, or died completely. Tobacco was planted in two additional pots in one of which the calcium oxid (in carbonate) amounted to 0.8 per cent. and magnesium oxid (in carbonate) to 0.2 per cent. In the other the amounts were 0.2 and 0.8 per cent., respectively. In the former the plant made a normal growth, while in the latter it died. May adds, in conclusion: "In these cases the action of the lime in counteracting the noxious influence of the magnesia was at most very limited."

In order to further test the matter, another series of experiments was made in soil which had received previously calcium carbonate and magnesium carbonate. Magnesium carbonate was used as before, but calcium oxid was added in calcium sulfate instead of in calcium carbonate as previously. Oats were planted, and May says of them as follows: "They continued to grow, were of good color, thrifty, and were free from shrivelling of the root system, as was the case before the calcium sulfate was added. These plants were brought to maturity, producing seed." The only case in which the growth was said not to be normal was that of the pot containing the equivalent of 0.9 per cent. of magnesium oxid in magnesium carbonate and 0.4 per cent. of calcium oxid in calcium sulfate. In this case the growth was "moderate" but not thrifty, indicating, according to May, "that there was not enough calcium in soluble form to wholly counteract the injurious effects of the magnesia. While the plants in the pots to which calcium sulfate had been added were growing, the pots containing the carbonates were replanted from time to time. The injurious results were continuous during the several months, the calcium carbonate not being able during a period of that length to counteract the effect of the excess of magnesia."

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[1] Die Landw. Vers. Sta. 41 Berlin, 1892, pp. 474, 475.

[2] Die Kali Düngung auf leichtem Boden, Berlin, 1890, p. 25.

[3] Bul. 1, U. S. Dept. of Agri., Bureau of Plant Industry, Washington, D. C., (1901), pp. 46, 47.

May apparently attributed the failure of the plants wholly to magnesia poisoning, and the sole reason in his opinion why the calcium carbonate failed to correct the condition was that it was not sufficiently soluble.

It should be remembered, however, that magnesium carbonate has been shown by various observers to be far more soluble in water, in carbonated water, and in ammonium chlorid,[1] than calcium carbonate, and doubtless the same is true in the case of other solvents. Indeed, Loew[2] calls attention to investigations by Treadwell and Reuter which show that one liter of water will hold only 0.385 gram calcium bicarbonate in solution, but that the same amount will hold 1.954 grams of magnesium bicarbonate, besides 0.715 gram magnesium carbonate, and even May mentions the same fact but fails to consider the possible bearing which such conditions may have had upon the reaction of the soil in his own experiments and the influence of this reaction upon plant growth.

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[1] Comey, A Dictionary of Chemical Solubilities, London and New York, 1896.

[2] Bul. No. 1, U. S. Dept. of Agr., Bureau of Plant Industry, Washington, D. C., 1901, p. 15.

In case magnesium carbonate was more soluble in May's soil solution, as affected by the regular nutrients and the probable presence of carbonic acid, than calcium carbonate, then it is not improbable that the combination of large percentages of magnesium carbonate with small percentages of calcium carbonate caused a greater degree of alkalinity in the soil than the reverse combination. Supposing such to have been the case, it is not surprising that such a condition should have been injurious to oats and cowpeas, both of which are better suited by an acid soil than either wheat or barley.[1] Furthermore, it has been shown by C. H. Shinn[2] that even these latter plants cannot endure considerable amounts of alkalinity.

This view of the matter would serve to explain in part the better results secured by May with other salts of magnesium and calcium than were obtained with the carbonates, and it also furnishes a reason for the greater effectiveness of a neutral salt like calcium sulfate as compared with the carbonate, which latter compound tends to promote alkalinity as shown by the litmus test, particularly in a soil when the conditions for the evolution of carbon dioxid and the consequent formation of bicarbonates would be good.

In an endeavor to throw somewhat definite light upon the possible influence of the soil reaction upon May's results, certain laboratory tests have been made. According to May[3] each 100 grams of soil must have received 0.2 gram of mono-potassium phosphate (KH_2PO_4), 0.2 gram of ammonium sulfate, 0.1 gram of potassium chlorid, and 0.1 gram of potassium nitrate. The amount of water in his soil doubtless varied considerably during the progress of his experiment, yet forty per cent. might be assumed as being near a maximum. Upon this basis the quantities of chemicals just mentioned would really be contained in about forty c. c.

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[1] Seventh An. Rpt. R. I. Expt. Sta., 1894, pp. 159, 160.

[2] Report Cal. Agr. Expt. Sta., 1892, 1893, and part of 1894, pp. 145-148.

[3] Bul. No. 1, U. S. Dept. of Agric., Bureau of Plant Industry, Washington, D. C., 1901, p. 46.

of soil water, provided none of them were absorbed. Owing to the variations in the last factor, dependent upon the soil, it could not well be estimated with accuracy. Three litres of solution were therefore made upon the foregoing basis, for the purpose of the experiment. May used in his study of magnesium poisoning amounts of magnesium oxid (in magnesium carbonate) ranging from 0.1 per cent. to 0.9 per cent. of the soil, and the same of calcium oxid (in calcium carbonate). Upon the basis of a soil containing forty per cent. of water this would represent a range per four-hundred c. c. of soil solution of from one to nine grams of the oxids. Accordingly, five four-hundred c. c. portions of nutrient solution taken from the three-litre lot, mentioned above, received the following additions of calcium and magnesium oxids (in both cases in carbonates), viz.:

Portion 1	9 grams calcium oxid.
Portion 2	9 grams calcium oxid. 1 gram magnesium oxid.
Portion 3	5 grams calcium oxid. 5 grams magnesium oxid.
Portion 4	1 gram calcium oxid. 9 grams magnesium oxid.
Portion 5	9 grams magnesium oxid.

The flasks containing these portions were allowed to stand in the laboratory at a temperature of from 15° to 18° C. for nearly a week, with frequent shaking during working hours. Each portion was then filtered, and the amounts of calcium oxid and magnesium oxid were determined in fifty c. c. portions of the filtrate. The results were as follows:

Portion No.	Grms. per 100 c. c. Magnesium oxid.	Calcium oxid.
1	0.0035	0.0074
2	0.0709	0.0067
3	0.1237	0.0019
4	0.1263	0.0027
5	0.1249	0.0008

In the filtrate from portion No. 1 considerable phosphoric acid was still in solution. In the filtrate from portion No. 2 only a trace of precipitate was formed from ten c. c. upon treatment with molybdic mixture, indicating that considerable of the magnesia had probably been utilized in precipitating the phosphorus. Under similar conditions the filtrates from portions Nos. 3, 4, and 5 gave merely a coloration with molybdic mixture.

The increase in alkalinity of portions Nos. 3. 4, and 5 over that of portion No. 2, as shown by cochineal, in solutions boiled to remove carbon dioxid, and by methyl orange, was about equivalent to the increase in the amount of magnesium oxid in the solutions, which indicates that after enough magnesium has been dissolved to effect the precipitation of the phosphoric acid, the alkalinity, as shown by these indicators, will be increased in proportion to the amount of magnesium in solution. It is reasonable to suppose that under the conditions of the pot experiment the total amount of magnesium dissolved would increase somewhat regularly with each increase of magnesium carbonate and the consequent surface exposed, with a corresponding effect upon the plant growth accompanying the increased alkalinity.

In the solubility experiment recorded above, however, where the circumstances for solution were more favorable, portion No. 3 had apparently become saturated with magnesium carbonate so that practically no more could be dissolved when the larger amounts in portions Nos. 4 and 5 were present.

May, as has been said, attributed the improvement wrought by the introduction of calcium carbonate in place of some of the magnesium carbonate in his experiment, solely to the assimilation of more calcium oxid by the plant, and hence to more normal proteid combinations with bases, but has paid no attention to the effect of the probably increased alkalinity.

It is of interest that May calls attention to the fact that, where carbonate of lime was quite inefficient in overcoming the unfavorable conditions caused by magnesium carbonate, the employment of calcium sulfate in the presence of the two carbonates improved the conditions wonderfully. This he attributed solely to the greater solubility of calcium sulfate, on which account more lime was assimilated by the plants, and hence the toxicity of the magnesium carbonate was overcome. Here again May apparently overlooked the fact that the calcium sulfate would react upon the magnesium carbonate which was in solution in such a way as to produce magnesium sulfate and calcium carbonate, a change which would lessen the alkalinity, and which took place, accompanied by the precipitation of calcium carbonate, when a calcium sulfate solution was added to one of the solutions which had been saturated by magnesium carbonate in our experiment.

Kearney and Cameron[1] cite an instance in their own experiments where "Magnesium carbonate ($MgCO_3$) in a solution which gave a strong hydroxyl reaction with phenolphthaleine allowed the roots to grow about as rapidly as in distilled water and to remain in about normal condition." When they added an excess of carbon dioxid, so that no free hydroxyl could be detected either before or after the experiment, a strongly toxic action upon the roots took place. They explain this upon the basis of there being a greater amount of magnesia in solution, and mention the appearance upon the roots of the plants under experiment of brownish spots such as are "produced by the readily soluble magnesium salts." With the corresponding calcium solution they also observed injury to plant growth for which they could offer no satisfactory explanation. In this connection it will be remembered that it was pointed out by Wheeler, Hartwell, and Tucker,[2] in 1895, that the alkalinity of a solution as concerns its reaction upon litmus is much greater if carbon dioxid is present with calcium carbonate than when it is not, and bearing in mind the fact that the reaction of soils as indicated by litmus has apparently a marked influence upon plant growth, it would not seem improbable that this factor might explain the results obtained by Kearney and Cameron. For, if the reaction of the solution caused the difficulty, it would be but natural that calcium carbonate should act as it did, and it leaves one in doubt also if the injury caused by the magnesium carbonate might not have been due, at least in part, to the same cause. Similarly it is possible that their experiments, mentioned in the same place, with sodium carbonate and calcium chlorid might find their explanation.

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[1] U. S. Dept. of Agric., Report No. 71, 1902, page 26.

[2] Eighth An. Report R. I. Agric. Exp. Sta., 1895, pages 243 and 244.

Circumstantial evidence is afforded by their own experiments that the reaction of the solution may in some cases have influenced Kearney and Cameron's results, for they state that with most mixed solutions the results secured with alfalfa and lupine plants were in close accord, but that a serious discrepancy occurred in a mixture of sodium bicarbonate, calcium sulfate, and calcium carbonate, toward which alfalfa roots were about twice as resistant as the roots of lupine.[1] In fact, in the experiments at the Rhode Island Experiment Station it has been shown that upon acid soil lupines may be injured by liming, and that alfalfa cannot succeed well until the acidity is materially reduced. In view of these facts, it is not surprising that alfalfa should have shown greater resistance than lupine in the alkaline solution which probably resulted from the combination of salts which they mention.

Enough has perhaps been said already to show the fallacies into which one may be led in attempting to explain too generally upon Loew's theory the injury sometimes observed in field practice in the use of manures which contain magnesium. By way of further illustrating the danger of applying conclusions drawn from experiments conducted under artificial conditions to field practice, certain results with calcium salts are of interest. If, after studying Kearney and Cameron's work,[2] indicating that calcium carbonate was incapable of correcting the unfavorable conditions for plant growth produced by calcium chlorid, one were to infer (as they did not) that this applied generally to soil conditions, the chance for error would be obviously great; since Wheeler and Hartwell[3] have shown that the poisonous action of calcium chlorid in a natural soil was entirely overcome by introducing calcium carbonate.

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[1] Ibid, page 38.

[2] Ibid, page 41.

[3] 15th An. Report, R. I. Agric. Exp. Sta., 1901–1902, pages 289–294.

It is not without interest that Loew,[1] who apparently has heretofore lost few, if any, opportunities to explain all injury resulting from the use of kainit and other substances containing magnesia by means of his theory of excessive nucleo-proteid combinations with magnesia, and without consideration of their effect upon the reaction of the soil, should now have pointed out that in certain of Kearney and Cameron's experiments calcium salts might have prevented injury from sodium carbonate as a result of reducing the alkalinity rather than on account of influencing the resulting ionizations. In fact it can hardly be doubted that May and others, including Loew himself, have aroused undue fear of magnesium poisoning in practical field operations as the result of attempting too frequently to reason from comparatively simple laboratory experiments as to what will take place in the soil complex. Indeed, it would appear that in following the ion theory in relation to the influence of salts upon plant growth, one has often to deal with the influence of undissociated salts and with the chemical reaction of the solution as concerns acidity and alkalinity, as well as with the influence of specific anions and cathions. If such is the case, all three factors, at least, must be kept continually in view instead of any one or two to the exclusion of the rest.

SOIL CULTURE EXPERIMENTS AT KINGSTON INDICATING THE DANGER OF DRAWING ERRONEOUS CONCLUSIONS CONCERNING A POISONOUS ACTION OF MAGNESIUM SALTS DUE TO A LACK OF LIME.

In many instances where injury from applications of magnesium salts in the field or in pot experiments has resulted, the observations have been limited to a single year or the experiments have been continued with the same pots and soil for but one season; and furthermore the chemical reaction of the soil has been quite generally disregarded.

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[1] Flora, 92 (1903), page 492 (foot note).

To illustrate the possibility of drawing erroneous conclusions from experiments conducted without careful attention to the acidity or alkalinity of the soil, and for only one season, certain experiments at this Station are full of significance. The natural granitic soil under experiment was quite acid in its reaction upon blue litmus paper, yet it contained about 0.5 per cent. of calcium oxid removable by strong hydrochloric acid. The experiments were conducted in pots 18 inches in diameter and 26 inches deep, which were sunk in the ground to within 2 inches of their tops. The regular manure, for each pot in the whole series for the first two years, was 30 grams acid phosphate, 20 grams nitrate of soda, and 10 grams muriate of potash. The third year it consisted of 30 grams basic slag meal, 30 grams dried blood, and 20 grams potassium-magnesium carbonate.

The first season the three check pots gave an average yield[1] of 43.69 grams of dried barley plants. Where magnesium chlorid was added at the rate of 19.16 grams per pot, the average yield was 46.47 grams. A further addition of 44 grams of caustic magnesia reduced the yield to 6.07 grams. With the magnesium poisoning idea in mind, and without regard to other factors, one would certainly have found in the result with the magnesium chlorid and caustic magnesia combination the fullest confirmation of Loew's theory. The good result with magnesium chlorid would have been explained by saying that that amount was helpful from a manurial standpoint, but that the addition of caustic magnesia increased the assimilable magnesium salts unduly in proportion to the lime present. Indeed, another series of pots in the experiment, receiving the same amount of magnesium chlorid and also 110 grams of calcium carbonate in lieu of the caustic magnesia, gave an average yield of 67.89 grams, thus surpassing any of the other results.

The second year the same check pots gave an average yield of but 3.65 grams of dried spring rye plants. By the addition of magnesium chlorid the average yield rose to 51.32 grams, and where both magnesium chlorid and caustic magnesia were employed it amounted to 49.71 grams.

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[1] For full details see Fifteenth An. Rpt. R. I. Expt. Sta. (1901–02), pp. 295–304.

From this it will be seen that injury had probably resulted from the acid phosphate and muriate of potash in the check pots. That the practically total failure of the crop in these pots could have been due to an almost complete lack of magnesia does not seem probable in view of the fact that soil from the same field contained about 0.2 per cent. of magnesia removable by strong hydrochloric acid, and, furthermore, successive crops of fairly good size could still be grown upon the same soil, where the other conditions were satisfactory, even without further magnesium salts. These results indicate, therefore, that the caustic magnesia was injurious the first year chiefly on account of its alkalinity, which was subsequently reduced by its union with carbonic acid so as to exert, the second season, a beneficial instead of an injurious influence. Again, the second season, where ammonium chlorid was added without magnesium salts, the average yield was reduced to 2.32 grams per pot, but instead of the yield being still further reduced by the caustic magnesia applied the year before, it rose, where both were employed, to 62.66 grams, while where calcium carbonate was used in place of the caustic magnesia it was but 50.53 grams.

The third year the regular manure for each pot in the experiment was changed as indicated previously, substituting one having an alkaline reaction. As a consequence, good results with oats were secured not only in the check pots, but in the others also. The average yield of the check pots was 88.68 grams per pot; with magnesium chlorid it was 84.39 grams; with both magnesium chlorid and caustic magnesia it was 87.92 grams. As concerns the groups of pots all of which received ammonium chlorid, 83.91 grams represent the average yield without further addition, 87.63 grams the yield where a further addition of calcium carbonate was made, and 89.52 grams where caustic magnesia was applied. In another case where ammonium chlorid was used and where the initial application of 44 grams of caustic magnesia was further supplemented by 59.17 grams of magnesium carbonate the second season, the yield amounted to 88.97 grams.

It must be evident, therefore, not only from what has preceded, but also from this presentation of facts, that great danger does exist of drawing erroneous conclusions as to the poisonous action of magnesium salts, *due to the presence of insufficient calcium oxid*, particularly when sufficient attention is not paid to the chemical reaction of the soil and to the effect of that reaction upon plant growth.

What has been said should in no wise be construed as an attack upon Loew's theory, nor as an attempt to discredit the idea that calcium may, under certain circumstances, be an antidote for magnesium poisoning, but, as has been stated before, to call attention to other factors which May and Loew do not seem to have considered sufficiently; and to point out that practical agriculturists may have been unduly alarmed by their writings concerning the danger of magnesium poisoning in practical field operations.

A FEW DATA CONCERNING THE PROPER RELATION OF LIME TO MAGNESIA.

Loew[1] states that "a certain ratio between these two nutrients will produce the most favorable results," and he adds further that the ratio will depend also upon the crop to be grown. The necessity of paying attention to this relation between the two constituents in certain soils derived from magnesian rocks may be unquestioned, yet this is possibly given undue prominence in the statement by May[2] that "it is also highly probable that the magnesia content of a great many soils is excessive to such an extent as to hinder them in producing maximum crops."

May[3] conducted a series of experiments for the purpose of ascertaining the best ratio between lime and magnesia for promoting "early germination and quick development of plants." In a comparison of calcium and magnesium oxids, in carbonates, in a trial of oats and cowpeas with a "Sea Island cotton soil," the best growth of each was in the soil containing 0.8 per cent. of calcium oxid and 0.2 per cent. of magnesium oxid. He states that when the calcium oxid was 0.6 per cent. or less and the magnesium oxid 0.4 per cent. or more, poor results were obtained. A normal growth of tobacco was also secured with the first-mentioned ratio, but when it was reversed plants died. A further test was made by him in five pots containing 0.5, 0.7, 0.8, and 0.9 per cent. of magnesium oxid with 0.4 per cent. of calcium oxid in each, but employed as sulfate. These pots had already received calcium oxid in calcium carbonate previously. Counting together the two lots of calcium oxid, the relations of calcium oxid to magnesium oxid were 9 to 5, 8 to 6, 7 to 7, 6 to 8, and 5 to 9. Oats were planted and good results were secured in all of the pots excepting the one with 0.1 per cent. of calcium oxid as carbonate and 0.4 per cent. as sulfate, associated with 0.9 per cent. of magnesium oxid as carbonate.

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[1] Bul. No. 3, U. S. Dept. of Agric., Bureau of Plant Industry, Washington, D. C., 1901, page 17.

[2] Ibid, page 38.

[3] Bul. No. 1, U. S. Dept. of Agric., Bureau of Plant Industry, Washington, D. C., 1901, pp. 46 and 47.

In a subsequent trial of wheat and oats, nitrate of calcium and nitrate of magnesium were employed in the relation of 0.5 per cent. of calcium oxid and 0.4 per cent. of magnesium oxid. This ratio proved superior to either 0.2 per cent of magnesium oxid and 0.7 per cent. of calcium oxid or the reverse ratio. A subsequent trial of oats in the same pots gave a corresponding result, and succeeding them cowpeas and tobacco were tried. The former plants grew best with the ratio which proved best for both wheat and oats. With the tobacco the most satisfactory results were obtained with relations of calcium oxid to magnesium oxid of 0.7 per cent. to 0.2 per cent. and of 0.6 per cent. to 0.3 per cent.

In still another soil culture experiment in pots with combinations of lime as sulfate and magnesia as carbonate, poor results were obtained by the addition of 0.68 per cent. of magnesium oxid as carbonate and but 0.2 per cent. of calcium oxid as sulfate. May states, in conclusion, that "the best proportion of soluble lime to soluble magnesia for the germination and growth of plants is about molecular weight 5 to 4 or actual weight 7 to 4." These figures are stated by May to refer to "soluble amounts—that is, to that portion directly available to the immediate needs of the plant."

Concerning magnesium carbonate, May says it was found that it might be in slight excess over calcium sulfate and still normal growth would result. With cereals, he says, this excess should not be greater than 2 to 1. In fact, May's results, though open in some particulars to interpretations somewhat different from those which he places upon them, seem, in many respects, to support strongly the theory of magnesium poisoning as affected by salts of lime. It is recognized by May that the whole problem depends not upon the relative total amounts of these two substances present in the soil, but upon that which is soluble or available to the plant at any given time.

Gössel[1] attributes to Loew the statement that, if a soil contains more magnesia than lime, it cannot produce maximum crops. In a study of the magnesium problem, Gössel employed water culture and soils. He states that in water-culture experiments with barley and horse-beans the best yield was obtained with lime and magnesia in the ratio of 0.4 to 1. He further adds, as a result of experiments with soils, that the statement, that a soil which contains more magnesia than lime cannot produce maximum crops, was demonstrated by his own experiments to be incorrect.

In view of a number of observations made at this Station, indicating a marked increase of magnesia in the dry matter of plants after magnesium salts had been applied as manures, and recognizing that these percentages present in the plant must in consequence bear a somewhat close relation to the quantities in the soil which are actually assimilable, it was thought to be of interest to determine by analytical means the range of magnesium percentages found in normal and abnormal crops grown in the presence of large and small quantities of magnesium salts. It was also to be assumed that possibly, by means of the analysis of the crop, valuable indications of the actual facts might be afforded in cases where excessive amounts of magnesia were present in soils, and that perhaps this could be learned much better than by a direct examination of the soil itself. This seemed particularly probable in view of the fact that fully satisfactory methods of telling the amount of the various and readily assimilable plant foods in soils, have not yet been elaborated.

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[1] Biedermann's Central-Blatt f. Agrikulturchemie 33 (1904), p. 226.

Referring to the analyses of barley given on page 231, the average of the lime and of the magnesia determinations shows a ratio of magnesia to lime when magnesium sulfate was employed of 1 to 1.13, and when magnesium salts were not present in the manures the ratio was 1 to 2.7.

In another experiment in the same style of pots, also sunk in the ground over drains and filled with subsoil and surface soil from another part of the "Plain," a few data of interest have been obtained. Every one of a group of three pots was manured as follows:

Grams per pot.	
13.47	sulfate of ammonia (agricultural grade).
25.00	dissolved boneblack.
10.00	muriate of potash.

One pot then received, in addition, 2.54 grams, another 5.08 grams, and the third 7.62 grams, of caustic magnesia. To two other pots the same manures were applied, excepting the omission of caustic magnesia and the use of wood-ashes as a substitute for the muriate of potash. The ashes were used in such a quantity as to furnish the same amount of actual potash as in the other case. Another pair of pots was manured with sulfate of ammonia, dissolved boneblack, and muriate of potash, but without either caustic magnesia or wood-ashes. None of these three groups of pots received lime in any combination, except such as was supplied in the wood-ashes and in the dissolved boneblack.

Barley.

Portion above ground. Cut "in the milk."

SPECIAL MATERIAL ADDED.	Pot No.	Crop dried at 100° C. (grms.)	PER CENT. IN DRY MATTER.		Ratio of the Magnesium oxid to the Calcium oxid.
			Magnesium oxid.	Calcium oxid.	
One-third ration of magnesium oxid............	32	72.59	0.227	0.266	1:1.2
Two-thirds ration of magnesium oxid............	37	94.56	0.293	0.193	1:0.7
Full ration of magnesium oxid..................	42	98.85	0.376	0.227	1:0.6
Wood-ashes..............	48	98.84	0.274	0.529	1:1.9
	53	98.13	0.280	0.527	1:1.9

From the foregoing it will be seen that where a one-third ration of caustic magnesia was applied the ratio of magnesia to lime in the dry matter of the barley plants was 1 to 1.2. By the use of a two-thirds ration the ratio became 1 to 0.7, and by the employment of a full ration of caustic magnesia the ratio was 1 to 0.6. In other words, the addition of the second amount of caustic magnesia had a very marked influence in increasing the relative amount of magnesia in the dry matter of the plants, though the third addition had but little further influence. Where wood-ashes were employed (which contain considerable amounts of calcium carbonate and relatively small amounts of magnesia) the ratio of magnesia to lime was in both instances 1 to 1.9. This experiment differs from the one with magnesium compounds referred to on page 234 by virtue of the fact that no calcium carbonate was added, to any of the pots, except that naturally associated with the wood-ashes. It will be observed that the yield was decidedly increased with each addition of caustic magnesia. It is not to be assumed, however, that this increase was occasioned more than to a limited extent by a direct manurial action of the magnesia, for it will be remembered that the soil was quite acid, and in two pots manured in other respects the same, but where magnesia was omitted, the yields amounted to but 4.53 and 6.88 grams per pot. In further support of this idea it should be stated that in the case of three pots manured like the two just mentioned, but to which sodium carbonate had been applied at rates of 5.53, 11.06, and 16.59 grams, respectively, the corresponding yields rose to 13.15, 34.09, and 72.56 grams of dry matter per pot. It can hardly be claimed that the increased yield brought about by the sodium carbonate was due to a liberation of magnesia, nor that the yields of 4.53 and 6.88 grams per pot, with the regular manures only, were accounted for by a lack of assimilable magnesia, for in other experiments with similar soil nearly maximum crops were obtained, even without magnesia, provided nitrate of soda served as a source of nitrogen instead of sulfate of ammonia.

Again, if Loew[1] is correct in his assumption that "one and the same molecule of magnesia can serve repeatedly as a carrier of phosphoric acid for the formation of nucleo-proteids and lecithin," it will not appear strange that a soil can still produce certain crops when the content of magnesia is very much smaller than that of the lime. It is realized that the points which have just been discussed do not bear directly upon the question of the best ratio of lime and magnesia, yet it seemed desirable to call attention to them, first, to show that the magnesia had probably exerted its chief effect in this instance as a neutralizer of the soil acidity, and, secondly, in order that the reader might not be led inadvertently to draw unwarranted conclusions from the results; which might readily occur if one had not come to realize sufficiently the influence of the soil reaction upon plant growth in both field and pot culture experiments.

The fact that the crop with a ratio of 1 to 1.2 of magnesia to lime was far poorer than one containing a ratio of 1 to 0.7 or even of 1 to 0.6, does not lend additional fear of magnesium poisoning. The fact that these experiments were conducted upon acid soil in no wise interferes with such a conclusion. Certainly these results would seem to controvert the statement attributed by Gössel to Loew concerning the necessary relation of magnesia to lime in soils.

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[1] Bul. No. 1, U. S. Dept. of Agric., Bureau of Plant Ind., Washington, D. C., 1901, page 15.

Still another series of experiments at this Station is of interest in this connection. The soil and pots were each the same as those described on page 230. Each pot in the entire lot had the following manures for two successive years, viz.:

Grams per pot.	
30	acid phosphate.
20	nitrate of soda.
10	muriate of potash.

To one series c. p. ammonium chlorid had now been added for the second season at the rate of 10.15 grams per pot, calcium carbonate having been applied the previous year at the rate of 110 grams per pot. To a second series c. p. hydrous magnesium chlorid had now been added for the second season at the rate of 19.16 grams per pot. To a single pot, which constituted the third series, 19.16 grams c. p. hydrous magnesium chlorid, and also 44 grams of caustic magnesia, had been added in 1898, and in 1899 the same amount of c. p. hydrous magnesium chlorid, and, in addition, 59.17 grams of c. p. magnesium carbonate, were applied. Below are given the pot numbers, the yields of air-dried spring rye, and the percentages of lime and magnesia found in the dry matter of the plants:

Series No.	Pot No.	Special applications.	Grms. of air-dried plants (in 1899).	PER CENT. IN DRY MATTER.	
				Calcium oxid.	Magnesium oxid.
1	25	Ammonium chlorid and calcium carbonate..................	50.50	0.71	0.11
	26		52.48	0.68	0.11
	27		48.60	0.69	0.11
		Average yield..	50.53		
2	53	Magnesium chlorid............	48.85	0.38	0.25
	54		50.90	0.38	0.23
	55		54.22	0.37	0.26
		Average yield..	51.32		
3	81	Magnesium chlorid, caustic magnesia, and magnesium carbonate.....................	41.41	0.11	0.61

From the foregoing it will be seen that there was no essential difference in the crop, exhibited between series No. 1 and series No. 2. In series No. 3 there was an unmistakable depression of yield which may have been caused by undue alkalinity, to an excessive amount of assimilable magnesia, or possibly to both causes acting at the same time. In series No. 1 the ratio of magnesia to lime, by actual weight, was 1 to 6.3; in series No. 2 the ratio was 1 to 1.5; and in series No. 3 it was 1 to 0.18 (equal to 5.6 of magnesia to 1 of lime). The conditions of the experiment are not such as to show whether a positive deficiency of magnesium as a plant food existed in series No. 1, nor is it probable, in view of the calcium sulfate associated with the acid phosphate, that a deficiency of calcium as plant food existed in series No. 2. At all events, in series No. 2, where the ratio of magnesia to lime was as 1 to 1.5, the average yield obtained was but slightly better than where the corresponding ratio was as 1 to 6.3. Furthermore, the differences between the averages have no significance after considering the variation in the individual yields of the pots of the two series. In other words, where the ratio of magnesia to lime was as 1 to 6.3 the germination and growth were essentially as good as where the relation was 1 to 1.5; hence the results in this particular throw doubt upon the conclusion by May[1] to the effect that the best relation of soluble magnesia to soluble lime "for the germination and growth of plants" is, actual weight, 1:1.75.

In this connection attention should also be called to certain earlier experiments at this Station[2] with beets (mangel-wurzel). They were conducted in pots eighteen (18) inches in diameter and twenty-six (26) inches deep. These were set in the ground over drain-tile to such a depth that the soil within and without the pots came to within from one and one-half to two inches of the tops. Natural granite soil and subsoil were employed at the rate of 100 pounds per pot of the former and 114 pounds of the latter. The regular manures applied the first year were as follows:

Grams per pot.	
17.38	nitrate of soda.
22.07	dissolved boneblack.
7.36	muriate of potash.

The second year the quantities of nitrate of soda, dissolved boneblack, and muriate of potash were increased to 20, 25, and 10 grams, respectively, per pot. In one case caustic magnesia was used, each year, at the rate of 7.62 grams per pot, in addition to the regular manures. In another case sodium carbonate was applied in each of the years at the rate of 16.6 grams per pot. In a third instance, air-slaked lime was applied, the first year, at the rate of 91.98 grams per pot, and the second year at the rate of 18.4 grams. The two applications of air-slaked lime were, together, equivalent to three tons per acre. The yields obtained, and the extra applications for the second year of the experiment, together with the percentages of lime and magnesia in the dry matter of the beets, are shown below:

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[1] l. c., page 52.

[2] Eighth An. Report R. I. Agric. Exp. Sta., 1895, pp. 261 to 265.

Pot No.	Extra applications.	Weight of air-dried beet-roots (grams).	PERCENTAGES IN DRY MATTER.		Ratio of Magnesium oxid to Calcium oxid.
			Calcium oxid.	Magnesium oxid.	
88	Caustic magnesia.........	126.3	0.196	0.442	1:0.4
90	Sodium carbonate.........	131.3	0.339	0.207	1:1.6
93	Air-slaked lime...........	148.2	0.715	0.161	1:4.4
94	Air-slaked lime...........	132.0	0.835	0.274	1:3.0
92	None.....................	91.3	0.684	0.163	1:4.2

In this experiment it will be seen that where no extra application was made the relation of magnesia to lime was as 1 to 4.2, and even when lime was added the proportion of lime was in one case only slightly greater and in the other less. By the employment of sodium carbonate the proportion of magnesia to lime was greatly increased, which was probably due, as indicated by other experiments at this Station, to a liberation of magnesia by the sodium salt. In this instance the ratio of magnesia to lime was 1 to 1.6. Where caustic magnesia was added the ratio was as 1 to 0.4. Had there been available for comparison the results from pots 88, 90, 93, and 94 only, there might have been a tendency to conclude that the lesser yield in pot 88 was due to there not being sufficient lime present to prevent a toxic action of the magnesia; but when it is borne in mind that where neither additional sodium carbonate nor caustic magnesia was applied, and where the ratio of magnesia to lime was 1 to 4.2, the yield was far less (pot No. 92) than in the instance with a ratio of 1 to 0.4, it must be obvious that one must look to the acidity of the soil or some other cause to explain the results, than to unfavorable nucleo-proteid combinations with magnesia due to a lack of assimilable lime. Furthermore, it is apparent in this instance, that an amount of magnesia more than twice that of the lime did not interfere with obtaining a yield superior to that produced where the amount of lime was more than four times as great as that of the magnesia. In view of the soil acidity and the beneficial action of basic substances which have been observed repeatedly under such conditions, it does not seem possible in this case that the fault in pot No. 92 was a dearth of magnesia as plant food.

It is hoped that opportunity will be afforded in the near future to pursue still further this study of the relations of lime and magnesia for various plants as exhibited by the chemical analysis of the plant and the amount of crop produced.

Once more evidence has been afforded that not all cases of poor results, where magnesia has been applied, are attributable to injury according to Loew's theory.

SUMMARY.

Of two lots of soil from the College and Station farm, one appeared to be benefited by magnesium salts in the presence of liberal amounts of the three essential elements of plant food and in the presence of sufficient calcium carbonate to preclude probable injury from acidity. Any probable deficiency of magnesia would be covered for many years by a single application of magnesian lime. Occasional applications of wood-ashes or double sulfate of potash and magnesia would accomplish the same result.

Indications are afforded that certain writers in attempting to explain injury from manures containing magnesia and from magnesium salts, according to Loew's theory of magnesium poisoning, have caused undue alarm as to danger in that specific way in actual farm practice, and, furthermore, many of the observations which have been cited in support of the theory admit of more ready explanation along other lines. It appears to be altogether too early to attempt to state what is the best relation of lime and magnesia for plants, for the reason that plants may, and doubtless do, differ tremendously in this particular, and certain important factors have been frequently ignored which should have been given consideration before attempting to draw definite conclusions in this line, even for small groups of plants.

MISCELLANEOUS ANALYSES

(Other than those which will be published in connection with special articles)

B L. HARTWELL AND J. W. KELLOGG.

I. Sulfate of ammonia.
II. Nitrate of soda.
III. Dried blood.
IV. Hen manure.

	Per cent.			
	I.	II.	III.	IV.
Nitrogen	20.20	16.08	11.99	4.10

GUANO.

	Per cent.
Phosphoric acid*	20.30
Nitrogen	3.29
Potassium oxid	4.28

TANKAGE.

	Per cent.
Phosphoric acid	7.64
Nitrogen	9.15

FINE GROUND BONE.

	Per cent.
Phosphoric acid	23.97
Nitrogen	2.49

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* The efficiency of the phosphoric acid in this material is being tested at the Station in comparison with phosphoric acid in fine ground bone, basic slag-meal and acid phosphate.

ACID PHOSPHATE.

	Per cent.
Soluble phosphoric acid	10.71
Reverted phosphoric acid	4.39
Insoluble phosphoric acid	1.25
Total phosphoric acid	16.35
Ferric and aluminic oxids	2.24

BASIC SLAG-MEAL.*

	Per cent.
Phosphoric acid	18.21
Silicious material	6.45

AIR-SLAKED LIME.

	Per cent.
Calcium oxid (lime)	57.37

SULFATE OF POTASH.

	Per cent.
Potassium oxid (potash)	48.37

MURIATE OF POTASH.

	Per cent.
Potassium oxid (potash)	51.26

CORN (MAIZE) KERNELS.

	Per cent.				
	I.	II.	III.	IV.	V.
Protein	9.35	9.19	9.94	10.56	8.94

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* This material has proved, after a ten-years' test at this Station, to be highly efficient *immediately*, and to possess lasting qualities which make it rank among the best phosphatic manures. It has been falsely classified as an iron ore, and a duty of one dollar per ton has been levied upon it as such. This is a piece of injustice to the farmers and of shortsightedness, as concerns the country generally, though it is in the interest of the steel and fertilizer trusts. Only a limited amount is produced in the United States where the price is so high that in many sections it can be imported much more cheaply from Europe, even including the duty and the cost of insurance and transportation.—H. J. WHEELER.

DISTILLER'S GRAINS.

	Per cent.
Water	7.04
Crude fiber	9.42
Crude fat	16.03

WHEAT BRAN.

	Per cent.
Water	4.94
Crude fiber	7.05
Crude fat	9.55

INDIAN CORN (MAIZE) LEAVES.*

	Per cent. in dry matter.	
	Frost-bitten part.	*Green part*
Crude ash	3.37	7.16
Crude fiber	27.97	28.98
Crude fat	.87	3.07
Protein	16.44	18.75
Nitrogen-free, extract	51.35	42.04
	100.00	100.00

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* In preparing the leaves for analysis the mid-ribs and the coarser parts, where the leaves join the stalks, were removed so that the parts analyzed would be composed of similar tissue. The portions of the leaves between the tip ends, which were frost-bitten, and the other ends, which constituted the green part, were discarded because partly frozen and partly green. The samples were collected about a week after the frost, no rain having fallen in the interim.

REPORT OF THE METEOROLOGIST.

NATHANIEL HELME.

Summary for 1903–1904.

Highest temperature	93.0°	July 10, 1903.
Lowest temperature	—16.0°	January 5, 1904.
Range for the year	109.0°	
Highest monthly mean	69.2°	July, 1903.
Lowest monthly mean	20.6°	January, 1904.
Highest daily mean	81.5°	July 10, 1903.
Lowest daily mean	—4.0°	January 4, 1904.
Mean temperature of the year	45.7°	

Precipitation (rain and melted snow).

Greatest in any 24 consecutive hours	2.68	inches, August, 1903.
Largest total for one month	9.70	inches, April, 1904.
Least total for one month	.75	inches, September, 1903.
Total snow-fall (unmelted)	53.00	inches.

Prevailing Winds.

Northeast, October, 1903; southwest, May, June, 1904; west, July, August, September, November, December, 1903, January February, March, April, 1904.

Weather.

Number of clear days in the year	156
Partly cloudy days	107
Cloudy days	103
Days with .01 inch or more of precipitation	118

SUMMARY BY MONTHS FOR 1903–1904.

Months.	Highest temperature.	Lowest temperature.	Mean temperature.	Precipitation (rain and melted snow), inches.	Snowfall (unmelted).	Clear days.	Partly cloudy days.	Cloudy days.	Days with .01 inch or more of precipitation.	Prevailing wind direction.
1903.										
July	93°	48°	69.2°	3.59	......	13	14	14	11	W.
August	85°	45°	64.1°	6.55	......	9	10	12	12	W.
September	88°	34°	61.8°	.75	......	17	7	6	3	W.
October	74°	24°	52.2°	3.05	Trace..	12	7	12	10	N.E.
November	73°	9°	37.9°	2.50	4	19	3	8	6	W.
December	52°	—3°	25.6°	3.77	9	16	8	7	10	W.
1904.										
January	48°	—16°	20.6°	5.45	24½	12	9	10	12	W.
February	48°	—4°	21.6°	4.21	9½	13	9	7	9	W.
March	60°	5°	32.8°	2.88	6	11	8	12	10	W.
April	66°	20°	43.1°	9.70	......	7	15	8	14	W.
May	81°	35°	57.9°	3.17	......	16	8	7	11	S.W.
June	92°	40°	61.9°	4.44	......	11	9	10	10	S.W.
Total	......	......	......	50.06	53	156	107	103	118	......
Mean	71.7°	19.7°	45.7°	......	......	......	......	......	......	......

The principal characteristics of the weather for each month were as follows:

July temperature and rainfall were each below the average for the month. The weather was generally favorable for gathering the hay crop, there being but four cloudy days in the month.

The mean temperature of August was 4° below the average, making it the coldest, in our fifteen years' record. The rainfall was above the average, but not the largest amount for the month, that of 1898 being three-tenths of an inch more and the largest for August on our record.

The mean temperature of September was slightly below the average, while the rainfall was less than one-fifth of the average for the month for 16 years. The first light frost of the fall formed on the 9th, and the first killing frost on the 29th, on low land.

The October rainfall was below the average, and there was a trace of snow on the 28th, the first that has fallen in the month since 1895. The mean temperature was slightly above the average.

There were no severe storms in November, and only one heavy rainfall. The first snow fell on the 6th. The temperature was below, and the rainfall but little more than one-half, the average for the month.

December was a month of variable weather. While there were some sudden changes, low temperatures prevailed, the mean temperature being below the average, making it the coldest month in 1903 and the coldest December on our record. On the afternoon of the 29th there was a severe thunder storm, accompanied by snow. The total precipitation was below the average.

January was also a month of variable weather, with frequent storms, some of them quite severe. The ground was covered with snow for the greater part of the month, and the number of continuous days of good sleighing was something unusual. The minimum temperature of 16° below zero on the 5th of the month was the lowest ever registered here as far as we know.

The February precipitation was less than, and the mean temperature far below, the average. It was the coldest February on our record. The mean temperature of the three winter months was 22.6°, while for 14 years previous the mean winter temperature was 28.5°.

The mean temperature of March was below the average and nearly 10° less than that of the same month in 1903. There were no severe storms, and the precipitation was less than one-half the average for the month for 16 years.

April precipitation was greatly in excess of the average, and double the normal for the month, for the past fifteen years. Another feature of the weather was the low temperature during the middle of the month, when, for 12 days in succession, the minimum temperature was below the freezing point. The cold and wet weather retarded the farmers' work to a considerable extent.

The precipitation in May was quite well distributed, and was below the average for the month. There was a large amount of sunshine, and the mean temperature was above the average for the month.

The June rainfall and temperature were each below the average for the month. There were some low temperatures about the middle of the month, and on the morning of the 14th there was a heavy white frost in exposed places on low land. The weather was very favorable to the growth of grass, and at the end of the month some persons had begun to make hay.

The following tables give the temperature, rainfall, wind direction, and character of the day for each day of the year; and a general summary for the years from January 1, 1890, to June 30, 1904, inclusive:

WEATHER SUMMARY FOR JULY, 1903.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	83°	58°	70.5°	.02	S.W.	Fair.
2	90	66	78.	....	S.W.	Clear.
3	84	63	73.5	....	W.	Fair.
4	80	57	68.5	....	S.W.	Clear.
5	76	51	63.5	....	S.W	Fair.
6	72	59	65.5	.90	S.W.	Cloudy.
7	83	59	71.	....	Variable.	Clear.
8	87	61	74.	....	W.	Fair.
9	92	68	80.	....	W.	Clear.
10	93	70	81.5	.01	S.W.	Clear.
11	90	69	79.5	....	W.	Clear.
12	85	60	72.5	....	W.	Fair.
13	68	61	64.5	.11	W.	Cloudy.
14	77	57	67.	.29	S.W.	Fair.
15	73	54	63.5	....	W.	Clear.
16	74	48	61.	....	W.	Clear.
17	80	53	66.5	....	S.W.	Clear.
18	73	55	64.	.31	S.	Cloudy.
19	70	57	63.5	1.00	W.	Fair.
20	72	52	62.	....	Variable.	Fair.
21	75	60	67.5	.75	N.E.	Fair.
22	77	61	69.	....	S.E.	Fair.
23	76	65	70.5	....	S.W.	Fair.
24	83	61	72.	....	N.W.	Clear.
25	82	55	68.5	....	W.	Clear.
26	87	65	76.	.03	W.	Clear.
27	73	54	63.5	....	N.W.	Clear.
28	73	49	61.	....	W.	Fair.
29	77	58	67.5	.01	S.	Fair.
30	82	65	73.5	.07	S.	Cloudy.
31	75	58	66.5	....	W.	Fair.
Sum......	2,462	1,829	2,145.5	3.59	....	....
Mean.....	79.4	59.	69.2	....	....	....

Maximum temperature...........93°. **Mean temperature**...............69.2°
Minimum temperature...........48°. **Prevailing wind**................west.

WEATHER SUMMARY FOR AUGUST, 1903.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	77°	52°	64.5	....	N.W.	Clear.
2	80	53	66.5	....	S.W.	Clear.
3	77	56	66.5	....	N.E.	Fair.
4	65	56	60.5	.55	E.	Cloudy.
5	57	54	55.5	2.68	E.	Cloudy.
6	67	55	61.	.34	N.E.	Cloudy.
7	79	56	67.5	....	N.W.	Fair.
8	68	45	56.5	....	S.W.	Clear.
9	66	48	57.	.28	E.	Cloudy.
10	81	58	69.5	....	S.W.	Fair.
11	72	56	64.	.35	Variable.	Cloudy.
12	80	58	69.	....	N.W.	Cloudy.
13	73	50	61.5	....	W.	Clear.
14	75	51	63.	....	W.	Fair.
15	80	52	66.	....	W.	Clear.
16	76	54	65.	....	S.	Cloudy.
17	77	55	66.	....	S.W.	Clear.
18	76	53	64.5	....	S.	Clear.
19	77	60	68.5	....	S.	Fair.
20	78	63	70.5	.12	S.E.	Cloudy.
21	80	56	68.	....	S.W.	Clear.
22	80	59	69.5	....	S.W.	Fair.
23	85	64	74.5	.50	S.W.	Fair.
24	78	57	67.5	....	W.	Fair.
25	78	54	66.	.36	S.W.	Cloudy.
26	68	55	61.5	....	N.E.	Fair.
27	76	53	64.5	....	N.E.	Fair.
28	66	55	60.5	.10	E.	Cloudy.
29	64	52	58.	.70	N.E.	Cloudy.
30	61	53	57.	.50	N.E.	Cloudy.
31	62	54	58.	.07	N.	0 Cloudy.
Sum......	2,279	1.697	1,988	6.55	....	....
Mean.....	73.5]	54.7	64.1	....	....	....

Maximum temperature..........85°.	Mean temperature..............64.1°.
Minimum temperature...........45°.	Prevailing wind................west.

WEATHER SUMMARY FOR SEPTEMBER, 1903.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	75°	55°	65.	....	W.	Clear.
2	69	57	63.	....	E.	Cloudy.
3	72	54	63	....	E.	Clear.
4	75	55	65.	....	S.W.	Clear.
5	78	58	68.	.20	S.W.	Fair.
6	70	51	60.5	....	N.	Clear.
7	71	45	58.	....	N.W.	Fair.
8	67	44	55.5	....	N.E.	Clear.
9	69	40	54.5	....	S.	Fair.
10	73	57	65.	....	S.W.	Cloudy.
11	85	62	73.5	....	N.W.	Clear.
12	80	52	66.	....	Variable.	Clear.
13	79	53	66.	....	S.W.	Clear.
14	88	64	76.	....	W.	Clear.
15	83	63	73.	....	S.W.	Clear.
16	78	63	70.5	....	E.	Cloudy.
17	79	67	73.	.20	S.	Cloudy.
18	70	52	61.	....	N.W.	Fair.
19	67	46	56.5	....	S.E.	Fair.
20	63	45	54.	....	N.E.	Cloudy.
21	68	49	58.5	....	N.	Fair.
22	81	46	63.5	....	W.	Clear.
23	77	49	63.	....	S.	Clear.
24	70	47	58.5	trace.	N.W.	Fair.
25	67	39	53.	....	N.W.	Clear.
26	71	43	57.	....	S.W.	Clear.
27	70	56	63.	.35	S.	Cloudy.
28	61	44	54	....	W.	Clear.
29	58	35	46.5	....	W.	Clear.
30	67	34	50.5	....	W.	Clear.
Sum......	2,184	1,525	1,854.5	.75	....	....
Mean.....	72.8	50.8	61.8	....	....	....

Maximum temperature...........88°.
Minimum temperature...........34°.
Mean temperature.............61.8°.
Prevailing wind...............west.

WEATHER SUMMARY FOR OCTOBER, 1903.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	72°	49°	60.5°		S.W.	Fair.
2	74	50	62.		N.E.	Fair.
3	66	49	57.5		E.	Clear.
4	65	42	53.5		S.E.	Clear.
5	74	55	64.5	.31	S.	Cloudy.
6	68	54	61.		N.E	Fair.
7	60	53	56.5	.20	N.E.	Cloudy.
8	66	56	61.	.11	E.	Cloudy.
9	62	56	59.	.07	E.	Cloudy.
10	56	49	52.5	.33	N.E.	Cloudy.
11	53	49	51.	.28	N.E.	Cloudy.
12	52	46	49.	.42	N.E.	Cloudy.
13	58	48	53.		N.E.	Cloudy.
14	70	42	56.		N.W.	Clear.
15	62	40	51.		Variable.	Clear.
16	69	44	56.5		S.E.	Cloudy.
17	66	58	62.	.86	S.	Cloudy.
18	60	39	49.5	.32	N.W.	Fair.
19	56	33	44.5		S.	Fair.
20	65	47	56.		S.W.	Clear.
21	62	42	52.		W.	Clear.
22	59	35	47.		Variable.	Clear.
23	67	48	57.5	.15	Variable.	Cloudy.
24	53	36	45.5		N.W.	Cloudy.
25	45	30	37.5		N.	Fair.
26	46	29	37.5		N.W.	Clear.
27	42	26	34.		N.W.	Clear.
28	47	24	35.5	trace.	W.	Fair.
29	60	25	42.5		W.	Clear.
30	69	40	54.5		W.	Clear.
31	72	44	58.		N.	Clear.
Sum......	1,896	1,338	1,617	3.05		
Mean.....	61.2	43.2	52.5			

Maximum temperature............74°.
Minimum temperature...........24°.
Mean temperature..............52.2°.
Prevailing wind...........northeast.

WEATHER SUMMARY FOR NOVEMBER, 1903.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	66°	42°	54.°	....	W.	Clear.
2	67	42	54.5	....	W.	Clear.
3	69	44	56.5	....	W.	Clear.
4	73	43	58.	....	W.	Clear.
5	62	47	54.5	.37	S.W.	Cloudy.
6	47	28	37.5	.31	N.W.	Cloudy.
7	34	22	28.	....	W.	Clear.
8	50	26	38.	....	W.	Clear.
9	62	32	47.	....	W.	Clear.
10	56	41	48.5	....	S.W.	Fair.
11	58	38	48.	....	N.E.	Clear.
12	57	37	47.	....	W.	Clear.
13	59	35	47.	....	W.	Clear.
14	45	35	40.	trace.	W.	Fair.
15	44	27	35.5	....	W.	Clear.
16	53	28	40.5	1.03	Variable.	Cloudy.
17	58	37	47.5	.55	S.W.	Cloudy.
18	52	27	39.5	....	W.	Cloudy.
19	39	19	29.	....	W.	Clear.
20	38	19	28.5	....	W.	Clear.
21	40	17	28.5	....	N.E.	Clear.
22	42	24	33.	....	N.	Cloudy.
23	43	26	34.5	.12	Variable.	Fair.
24	44	27	35.5	....	W.	Clear.
25	30	17	23.5	....	W.	Clear.
26	31	9	20.	....	W.	Clear.
27	28	10	19.	trace.	W.	Cloudy.
28	33	17	25.	....	N.W.	Clear.
29	24	12	18.	.12	N.	Cloudy.
30	33	12	22.5	....	W.	Clear.
Sum......	1,437	840	1,138.5	2.50	....	....
Mean.....	47.9	28	37.9	....	....	....

Maximum temperature...........73°.	**Mean temperature**.............37.9°.
Minimum temperature............9°.	**Prevailing wind**................west.

WEATHER SUMMARY FOR DECEMBER, 1903.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	33°	14°	23.5°		N.E.	Clear.
2	35	21	28.		N.E.	Cloudy.
3	32	23	27.5	.19	N.E.	Cloudy.
4	37	25	31.		N.W.	Fair.
5	43	23	33.		S.W.	Fair.
6	37	18	27.5		W.	Clear.
7	38	18	28.		S.W.	Clear.
8	45	23	34.		W.	Clear.
9	46	27	36.5	.60	N.E.	Cloudy.
10	49	27	38.		S.W.	Clear.
11	35	21	28.		W.	Clear.
12	41	16	28.5		W.	Clear.
13	52	23	37.	.67	W.	Fair.
14	26	13	19.5		W.	Clear.
15	25	10	17.5		W.	Fair.
16	26	7	16.5		W.	Clear.
17	28	7	17.5		W.	Clear.
18	19	7	13.		W.	Clear.
19	30	4	17.		W.	Clear.
20	52	22	37.	1.27	S.E.	Cloudy.
21	44	32	38.		W.	Fair.
22	40	20	30.	.08	W.	Fair.
23	34	13	23.5		W.	Clear.
24	44	29	36.5	.02	S.W.	Cloudy.
25	39	32	35.5	.18	S.W.	Cloudy.
26	32	1	16.5	.20	W.	Fair.
47	24	—3	10.5	.10	W.	Fair.
28	26	5	15.5		W.	Clear.
29	30	0	15.	.51	Variable.	Cloudy.
30	30	8	19.		W.	Clear.
31	23	9	16.		W.	Clear.
Sum......	1.095	495	795.	3.77		
Mean.....	35.3	16	25.6			

Maximum temperature...........52°.	Mean temperature.............25.6°.
Minimum temperature.........— 3°.	Prevailing wind................west.

WEATHER SUMMARY FOR JANUARY, 1904.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	33°	18°	25.5°	....	W.	Fair.
2	18	3	10.5	.60	N.	Cloudy.
3	9	—5	2.	.60	N.W.	Fair.
4	5	—13	—4.	....	W.	Clear.
5	20	—16	—2.	....	W.	Clear.
6	25	—6	9.5	....	W.	Fair.
7	32	16	24.	trace.	S.E.	Fair.
8	30	13	21.5	.30	N.E.	Cloudy.
9	32	26	29.	.25	W.	Fair.
10	32	15	23.5	....	W.	Clear.
11	28	10	19.	....	N.E.	Clear.
12	34	21	27.5	....	Variable.	Cloudy.
13	44	25	34.8	.92	N.E.	Cloudy.
14	42	25	33.5	....	S.W.	Clear.
15	27	15	21.	....	W.	Clear.
16	39	9	24.	.25	S.W.	Fair.
17	32	10	21.	....	W.	Clear.
18	15	—2	6.5	....	W.	Clear.
19	13	—7	5.	....	W.	Clear.
20	27	0	13.5	.16	W.	Cloudy.
21	30	22	26.	.07	N.E.	Cloudy.
22	46	27	36.5	1.00	N.E.	Cloudy.
23	48	40	44.	.05	S.W.	Cloudy.
24	42	22	32.	....	W.	Fair.
25	22	9	15.5	....	W.	Clear.
26	41	9	25.	.70	E.	Fair.
27	41	11	26.	....	W.	Clear.
28	25	5	15.	....	S.W.	Fair.
29	23	14	18.5	.45	N.	Cloudy.
30	33	15	24.	....	Variable.	Clear.
31	40	18	29.	....	S.W.	Cloudy.
Sum......	928	349	638.5	5.45	....	....
Mean.....	29.9	11.3	20.6	....	....	....

Maximum temperature...........48°. **Mean temperature.............20.6°.**
Minimum temperature.........—16°. **Prevailing wind................west.**

WEATHER SUMMARY FOR FEBRUARY, 1904.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	38°	12°	25.°	.09	W.	Fair.
2	33	1	17.	....	S.W.	Fair.
3	33	12	22.5	....	W.	Clear.
4	20	7	13.5	....	W.	Clear.
5	26	7	16.5	....	W.	Fair.
6	43	17	30.	.35	S.W.	Cloudy.
7	45	34	39.5	....	S.	Cloudy.
8	40	8	24.	....	W.	Clear.
9	14	2	8.	....	W.	Clear.
10	27	—1	13.	....	W.	Clear.
11	25	7	16.	....	N.W.	Clear.
12	26	5	15.5	....	W.	Clear.
13	32	14	23.	.03	N.	Cloudy.
14	28	23	25.5	.20	E.	Cloudy.
15	31	11	21.	.27	N.W.	Fair.
16	11	—4	3.5	....	W.	Clear.
17	20	1	10.5	....	W.	Clear.
18	30	0	15.	....	W.	Fair.
19	25	19	22.	.30	W.	Cloudy.
20	38	9	23.5	....	W.	Clear.
21	40	12	26.	....	S.E.	Fair.
22	48	31	39.5	2.28	S.W.	Fair.
23	40	22	31.	....	S.W.	Clear.
24	35	25	30.	41.	N.W.	Fair.
25	25	7	16.	....	W.	Clear.
26	27	4	15.5	....	W.	Clear.
27	32	10	21.	....	N.E.	Fair.
28	37	24	30.5	.28	S.E.	Cloudy.
29	37	25	30.	....	N.E.	Cloudy.
Sum......	906	344	625.	4.21	....	....
Mean.....	31.2	11.9	21.6	....	....	....

Maximum temperature...........48°.
Minimum temperature.........— 4°.

Mean temperature.............21.6°.
Prevailing wind.................west.

WEATHER SUMMARY FOR MARCH, 1904.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	33°	26°	29.5°	.50	N.E.	Cloudy.
2	41	28	34.5	....	Variable.	Cloudy.
3	45	29	37.	.18	Variable.	Cloudy.
4	34	12	23.	....	W.	Clear.
5	24	5	14.5	....	E.	Clear.
6	33	17	25.	....	E.	Fair.
7	47	30	38.5	.99	E.	Cloudy.
8	53	34	43.5	....	W.	Fair.
9	36	19	27.5	....	W.	Clear.
10	32	16	24.	....	W.	Clear.
11	30	24	27.	.08	N.E.	Cloudy.
12	40	16	28.	....	W.	Clear.
13	37	15	26.	....	W.	Clear.
14	37	16	26.5	....	S.W.	Fair.
15	35	24	29.5	.20	W.	Cloudy.
16	36	23	29.5	....	W.	Clear.
17	30	13	26.	....	S.W.	Clear.
18	36	26	31.	.55	Variable.	Fair.
19	47	25	36.	....	S.	Fair.
20	49	28	38.8	.05	W.	Fair.
21	47	22	34.5	....	Variable.	Fair.
22	41	30	35.5	.05	S.E.	Cloudy.
23	60	36	48.	.09	W.	Cloudy.
24	58	32	45.	....	S.W.	Clear.
25	56	30	43.	....	S.E.	Cloudy.
26	59	40	49.5	....	W.	Cloudy.
27	41	29	35.	trace.	N.E.	Cloudy.
28	38	23	30.5	....	S.W.	Fair.
29	46	20	33.	....	W.	Clear.
30	47	24	35.5	....	S.	Clear.
31	41	26	33.5	.19	E.	Cloudy.
Sum......	1,298	738	1,018	2.88	....	....
Mean.....	41.9	23.8	32.8	....	....	....

Maximum temperature...........**60°.** **Mean temperature**.............**32.8°.**
Minimum temperature........... **5°.** **Prevailing wind**................**west.**

WEATHER SUMMARY FOR APRIL, 1904.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	46°	30°	38.°	1.90	Variable.	Cloudy.
2	56	34	45.	....	W.	Fair.
3	42	28	35.	....	W.	Fair.
4	51	20	35.5	....	W.	Clear.
5	65	30	47.5	....	W.	Clear.
6	58	36	47.	....	S.E.	Fair.
7	60	38	49.	.15	S.W.	Fair.
8	56	38	47.	.02	E.	Fair.
9	49	41	45.	1.46	N.E.	Cloudy.
10	62	41	51.5	.66	S.W.	Fair.
11	54	38	46.	.07	W.	Fair.
12	48	36	42.	.56	S.	Fair.
13	49	29	39.	....	W.	Clear.
14	39	24	31.5	.11	S.W.	Fair.
15	49	24	36.5	....	S.W.	Fair.
16	39	28	33.5	.53	N.W.	Fair.
17	49	32	40.5	....	N.W.	Clear.
18	53	31	42.	....	S.W.	Fair.
19	56	28	42.	.12	W.	Cloudy.
20	35	20	27.5	....	W.	Fair.
21	58	30	44.	....	W.	Fair.
22	57	30	43.5	....	S.	Clear.
23	55	29	42.	....	S.W.	Clear.
24	55	31	43.	....	S.	Clear.
25	66	40	53.	.05	S.	Clear.
26	60	43	51.5	....	E.	Cloudy.
27	45	37	41.	1.48	N.E.	Cloudy.
28	54	38	46.	2.03	N.E.	Cloudy.
29	56	44	50.	.56	N.E.	Cloudy.
30	66	48	57.	....	S.W.	Fair.
Sum......	1,588	996	1,292	9.70	....	....
Mean.....	52.9	33.2	43.1	....	....	....

Maximum temperature...........66°.	**Mean temperature.............43.1°.**
Minimum temperature...........20°.	**Prevailing wind................west.**

WEATHER SUMMARY FOR MAY, 1904.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	63°	40°	51.5°	....	E.	Fair.
2	63	39	51.	....	Variable.	Clear.
3	64	35	49.5	....	E.	Clear.
4	69	38	53.5	....	S.W.	Clear.
5	74	43	58.5	....	S.W.	Clear.
6	67	43	55.	....	E.	Clear.
7	72	42	57.	....	S.W.	Clear.
8	73	47	60.	....	S.W.	Clear.
9	66	52	59.	1.25	Variable.	Cloudy.
10	78	50	64.	....	S.W.	Fair.
11	72	52	62.	.07	W.	Fair.
12	65	43	54	....	W.	Clear.
13	72	47	59.5	....	Variable.	Clear.
14	66	47	56.5	....	N.	Fair.
15	56	48	52.	.11	S.E.	Cloudy.
16	60	46	53.	.04	S.W.	Fair.
17	64	43	53.5	.13	E.	Cloudy.
18	61	51	56.	.04	N.E.	Cloudy.
19	57	48	52.5	.59	N.E.	Cloudy.
20	65	48	56.5	.03	S.W.	Fair.
21	71	49	60	....	S.W.	Clear.
22	72	48	60.	....	S.W.	Clear.
23	69	51	60.	....	S.W.	Clear.
24	80	54	67.	....	S.	Fair.
25	78	58	68.	.12	Variable.	Clear.
26	81	57	69.	....	S.W.	Clear.
27	74	50	62.	.04	S.W.	Clear.
28	74	44	59.	....	N.W.	Clear.
29	75	47	61.	....	Variable.	Fair.
30	67	51	59.	.75	S.	Cloudy.
31	66	52	59.	....	E.	Cloudy.
Sum......	2,134	1,453	1,793.5	3.17	....	....
Mean.....	68.8	46.9	57.9	....	....	....

Maximum temperature...........81°.
Minimum temperature...........35°.
Mean temperature.............57.9°.
Prevailing wind...........southwest.

WEATHER SUMMARY FOR JUNE, 1904.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	58°	51°	54.5°	.57	N.E.	Cloudy.
2	62	46	54.	....	N.	Cloudy.
3	70	48	59.	.19	N.E.	Fair.
4	72	55	63.5	....	Variable.	Fair.
5	76	54	65.	....	S.W.	Clear.
6	72	53	62.5	....	E.	Cloudy.
7	70	52	61.	.38	S.E.	Cloudy.
8	67	58	62.5	1.38	E.	Cloudy.
9	58	48	53.	.10	N.E.	Cloudy.
10	58	44	51.	....	E.	Fair.
11	71	40	55.5	....	Variable.	Clear.
12	68	45	56.5	....	N.	Clear.
13	62	42	52.	....	E.	Fair.
14	61	41	51.	....	S.W.	Clear.
15	67	42	54.5	....	S.W.	Clear.
16	72	52	62.	.10	S.	Cloudy.
17	71	55	63.	....	S.	Fair.
18	79	52	65.5	....	S.W.	Fair.
19	79	56	67.5	....	S.	Clear.
20	80	57	68.5	....	S.W.	Clear.
21	76	61	68.5	.39	S.W.	Fair.
22	82	61	71.5	.15	S.W.	Fair.
23	72	53	62.5	....	Variable.	Clear.
24	74	49	61.5	....	S.W.	Clear.
25	81	55	68.	....	S.W.	Fair.
26	92	64	78.	trace.	W.	Clear.
27	83	60	71.5	....	N.W.	Clear.
28	72	54	63.	....	N.E.	Fair.
29	75	56	55.5	1.09	E.	Cloudy.
30	72	61	66.5	.09	E.	Cloudy.
Sum......	2,152	1,565	1,858.5	4.44	....	....
Mean.....	71.7	52.2	61.9	....	....	....

Maximum temperature...........92°.
Minimum temperature...........40°.
Mean temperature.............61.9°.
Prevailing wind...........southwest.

SUMMARY JANUARY 1, 1890, TO JUNE 30, 1904, INCLUSIVE.

	Maximum temperature.	Minimum temperature.	Mean temperature.	Number of clear days.	Partly cloudy days.	Cloudy days.	Days with .01 inch or more of precipitation.	Total precipitation, inches.
1890	91°	3°	48.3°	99	143	123	120	59.25
1891	94	5	49.4	116	154	95	83	49.88
1892	92	—1	47.8	147	116	103	89	42.58
1893	92	—6	46.5	126	130	109	131	57.33
1894	93	—9	48.6	110	130	125	114	48.19
1895	95	—7	48.2	128	114	123	108	49.28
1896	93	—11	47.7	131	112	123	109	49.87
1897	90	—1	48.3	129	126	110	128	54.25
1898	95	—4	48.8	110	114	141	131	72.21
1899, January 1 to July 1	95	—10	42.1	77	44	60	59	26.79
July 1, 1899, to July 1, 1900	90	—5	48.3	141	113	111	102	51.67
July 1, 1900, to July 1, 1901	97	—9	48.4	134	97	134	114	48.47
July 1, 1901, to July 1, 1902	93	—1	48.	138	116	111	109	53.14
July 1, 1902, to July 1, 1903	90	—12	48.3	138	96	131	103	59.27
July 1, 1903, to July 1, 1904	93	—16	45.7	156	107	103	118	50.06

Average temperature, 14½ years..........................47.6°.
Average precipitation, 14½ years..................53.26 inches.

REPORT OF THE TREASURER.

THE RHODE ISLAND STATE AGRICULTURAL EXPERIMENT STATION, *in account with the* UNITED STATES APPROPRIATION, 1903–1904.

1904.	DR.		
	To receipts from the treasurer of the United States as per appropriation for fiscal year ended June 30, 1904, as per act of Congress approved March 2, 1887		$15,000 00
1904.	CR.		
	By Salaries	$8,758 84	
	Labor	1,561 54	
	Publications	71 65	
	Postage and stationery	283 52	
	Freight and express	115 49	
	Heat, light, water, and power	658 94	
	Chemical supplies	83 72	
	Seeds, plants, and sundry supplies	336 42	
	Fertilizers	243 14	
	Feeding-stuffs	563 70	
	Library	605 04	
	Tools, implements, and machinery	699 37	
	Furniture and fixtures	33 02	
	Scientific apparatus	44 14	
	Live stock	28 35	
	Traveling expenses	174 69	
	Contingent expenses	15 00	
	Buildings and repairs	723 43	
			$15,000 00

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the Rhode Island Agricultural Experiment Station for the fiscal year ended June 30, 1904; that we have found the same well kept and classified as above, and that the receipts for the year from the treasurer of the United States are shown to have been $15,000, and the corresponding disbursements $15,000, for all of which proper vouchers are on file, and have been examined by us and found correct, thus leaving no balance.

And we further certify that the expenditures have been solely for the purposes set forth in the act of Congress approved March 2, 1887.

CHARLES DEAN KIMBALL,
C. H. COGGESHALL,
Auditors.

MELVILLE BULL, *Treasurer, in account with the* RHODE ISLAND STATE AGRICULTURAL EXPERIMENT STATION, *for the year ending June* 30, 1904.

1904.	DR.	
To balance from last year		$2,157 72
Station receipts		534 53
Interest		98 75
		$2,791 00
1904.	**CR.**	
To publications		$11 15
Seeds, plants, and sundry supplies		12 69
Traveling expenses		80 57
Contingent expenses		2 88
Postage and stationery		31 35
Buildings and repairs		41 05
Balance		2,611 31
		$2,791 00

This certifies that we, the undersigned, auditing committee of the Board of Managers of the Rhode Island College of Agriculture and Mechanic Arts, have examined the accounts of Melville Bull, treasurer of the Rhode Island State Agricultural Experiment Station, and find the same correct.

The total receipts were $2,791, and the total expenditures were $179.69, thus leaving a balance to new account of $2,611.31.

CHARLES DEAN KIMBALL,
C. H. COGGESHALL,
Auditors.

EXCHANGES.

Aboriculture, Connersville, Ind.
Agricultural Advertising, Pittsburg, Pa.
Agricultural Epitomist, Spencer, Ind.
Agricultural Gazette of New South Wales, Australia.
Agricultural Ledger, Calcutta, India.
American Cultivator, Boston, Mass.
American Fancier, Johnstown, N. Y.
American Hay, Flour, and Feed Journal, New York, N. Y.
American Horse Breeder, Boston, New York, and Chicago.
American Philosophical Society, Proceedings of the Society.
American Poultry Advocate, Syracuse, N. Y.
American Poultry Journal, Chicago, Ill.
American Sheep Breeder and Wool Grower, Chicago, Ill.
American Stock Farm, The, Winona, Minn.
American Stock Keeper, Boston, Mass.
American Sugar Industry and Beet Sugar Gazette, The, Chicago, Ill.
Breeders' Gazette, Chicago, Ill.
Bulletins of the Botanical Department of Jamaica, and Reports of Public Gardens and Plantations.
Bulletins of the New York State Museum.
Chicago Daily Drovers' Journal, Chicago, Ill.
Colman's Rural World, St. Louis, Mo.
Connecticut Farmer, Hartford, Conn.
Current Numbers of Minnesota Botanical Studies, University of Minnesota.
Egg Reporter, The, St. Louis, Mo.
Elgin Dairy Report, Elgin, Ill.
Evening Telegram, Providence, R. I.
Farm and Home, Springfield, Mass.

Farm and Live Stock Journal, Detroit, Mich.
Farm, Field, and Fireside, Chicago, Ill.
Farm Home, Springfield, Mass.
Farm Journal, Philadelphia, Pa.
Farm Poultry, Boston, Mass.
Farm, Stock, and Home, Minneapolis, Minn.
Farmers' Advocate, London, Ontario.
Farmers' Guide, Huntington, Ind.
Farmers' Review, The, Chicago, Ill.
Farmers' Sentinel, Milwaukee, Wis.
Farmers' Tribune, Des Moines, Iowa.
Farmers' Voice, Chicago, Ill.
Feather, The, Washington, D. C.
Feathered World, The, London, England.
Flour and Feed, Waukegan, Ill.
Fruit Grower, The, St. Joseph, Mo.
Hoard's Dairyman, Fort Atkinson, Wis.
Holstein-Friesian Register, Brattleboro, Vt.
Homestead, The, Des Moines, Iowa.
Hope Valley Free Press, Hope Valley, R. I.
Hospodarske Listy, Chicago, Ill.
Indiana Farmer, Indianapolis, Ind.
Inland Poultry Journal, Indianapolis, Ind.
Journal Royal Horticultural Society, London, England.
Kansas Farmer, Topeka, Kansas.
Kimball's Dairy Farm, Waterloo, Iowa.
L'Aviculture Belge, Liege.
Live Stock and Dairy Journal, The, Fresno, Cal.
Maryland Agricultural Quarterly, College Park, Md.
Massachusetts Ploughman, Boston, Mass.
Metropolitan and Rural Home, The, New York, N. Y.
Miscellaneous Publications, Department of Agriculture and Mines, National.
Modern Farmer and Busy Bee, The, St. Joseph, Mo.

National Farmer and Stock Grower, National Stock Yards, Ill.
National Stockman and Farmer, Pittsburg, Pa.
Nebraska Farmer, Omaha, Neb.
New England Farmer, Boston, Mass.
New England Homestead, Springfield, Mass.
New Farm, Preston, Md.
New Hampshire Farmer and Weekly Union, Manchester, N. H.
New York Tribune and Farmer, New York, N. Y.
Nut Grower, The, Poulan, Ga.
Northwest Horticulturist, Tacoma and Seattle, Wash.
Ohio Farmer, Cleveland, Ohio.
Ohio Poultry Journal, Dayton, Ohio.
Oregon Agriculturist, Portland, Ohio.
Orff's Farm and Poultry Review, St. Louis, Mo.
Poultry Gazette, Kansas City, Kansas.
Poultry Herald, St. Paul, Minn.
Poultry Item, Fricks, Pa.
Poultry Keeper, Parkesburg, Pa.
Poultry Standard, Stamford, Conn.
Poultry Success, Des Moines, Iowa.
Poultry Topics, Lincoln, Neb.
Practical Farmer, The, Philadelphia, Pa.
Practical Fruit Grower, Springfield, Mo.
Providence News, Providence, R. I.
Publications of the Florida Department of Agriculture.
Publications of the Department of Agriculture, Mysore State, India.
Publications of the Imperial Agricultural Experiment Station, Nishigahara, Tokyo, Japan.
Publications of the Maine State Board of Agriculture.
Publications of the Massachusetts State Board of Agriculture.
Publications of the Department of Agriculture, New Zealand.
Publications of the North Carolina State Board of Agriculture.
Publications of the Department of Agriculture, University College, North Wales.

Publications of the Ohio State Board of Agriculture.
Publications of the Pennsylvania Department of Agriculture.
Publications of the Rhode Island State Board of Agriculture.
Publications of the Department of Agriculture, Victoria.
Publications of the Virginia Department of Agriculture.
Publications of the Department of Agriculture of Western Australia.
Queensland Agricultural Journal, Australia.
Reliable Poultry Journal, Quincy, Ill.
Republic, The, St. Louis, Mo.
Rock Products, Louisville, Ky.
Rural New-Yorker, New York, N. Y.
Rural World, London, England.
Skandinavisk Farmer Journal, Minneapolis, Minn.
Southern Farm Magazine, Baltimore, Md.
Southern Fancier, Atlanta, Ga.
Southern Planter, Richmond, Va.
Successful Farming, Des Moines, Iowa.
Successful Poultry Journal, Chicago, Ill.
Sugar Beet, The, Philadelphia, Pa.
Sun, The, Baltimore, Md.
Sec. da Agr. Estado de Sao Paulo, Boletim da Agriculture.
Texas Farmer, Dallas, Texas.
Trade, The, Baltimore, Md.
Transvaal Agricultural Journal, India.
Up-to-Date Farming and Gardening, Indianapolis, Ind.
Wallace's Farmer, Des Moines, Iowa.
Western Fruit Grower, St. Joseph, Mo.
W. Weedel & Co.'s Colonial Dairy Produce Report, London, England.
Weekly Inter-Ocean, The, Chicago, Ill.
West Virginia Farm Review, Charleston, W. Va.
Wilson Bulletins, Wilson Ornithological Club, Oberlin, Ohio.
Wisconsin Agriculturist, Racine, Wis.
Yearbook and Current Publications der Deutschen Landwirtschafts-Gessellschaft.

Directions for Binding the Bulletins and Reports of the Rhode Island Experiment Station.

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BULLETINS

AND

ANNUAL REPORT

OF THE

RHODE ISLAND AGRICULTURAL EXPERIMENT STATION,

FOR THE

YEAR ENDING JUNE 30,

1904.

PROVIDENCE:
E. L. FREEMAN & SONS, STATE PRINTERS.
1905.

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OF THE

BULLETINS AND ANNUAL REPORT

OF THE

RHODE ISLAND AGRICULTURAL EXPERIMENT STATION,

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YEAR ENDING JUNE 30, 1904.

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State of Rhode Island and Providence Plantations.

EIGHTEENTH ANNUAL REPORT

OF THE

RHODE ISLAND

AGRICULTURAL EXPERIMENT STATION, Kingston

1904-1905.

PART II.

OF THE

EIGHTEENTH ANNUAL REPORT

OF THE

CORPORATION, BOARD OF MANAGERS

OF THE

Rhode Island College of Agriculture and Mechanic Arts,

MADE TO THE

GENERAL ASSEMBLY AT ITS JANUARY SESSION, 1906.

[PARTS I. AND III. OF THIS REPORT — REPORT OF PRESIDENT AND BOARD OF MANAGERS AND COLLEGE CATALOGUE — ARE PRINTED UNDER SEPARATE COVERS.]

PROVIDENCE, R. I.:
E. L. FREEMAN & SONS, PRINTERS TO THE STATE.
1906.

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RHODE ISLAND

College of Agriculture and Mechanic Arts.

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M. A. Blake, B. Sc.	Assistant, Horticulture.
James W. Kellogg,* B. Sc.	First Assistant, Chemistry.

OTHER MEMBERS OF THE STATION STAFF.

J. P. Gray, B. Sc.	Assistant, Chemistry.
Matthew Steel,* M. Sc.	Assistant, Chemistry.
P. H. Wessels, B. Sc.	Assistant, Chemistry.
Nathaniel Helme	Meteorology.
Beulah A. Hoitt	Stenographer and Accountant.
————————	Stenographer and Librarian.

The publications of the Station will be mailed free on request to any one in Rhode Island interested in agriculture. The Station desires the co-operation of the farmers of the State in the work of investigation, and any facts of special interest concerning animal or vegatable growth or disease are solicited. Visitors are always welcome. Railway station, telegraph, express, and post-office—Kingston, Rhode Island. Long distance telephone, Narragansett Pier exchange.

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*Appointed expert in the Bureau of Soils of the Department of Agriculture, Washington, D. C., though still located at this Station engaged in co-operative work between the Bureau and the Station.

LETTER OF TRANSMITTAL.

To His Excellency, George H. Utter, Governor, and the Honorable the General Assembly of the State of Rhode Island, at its January Session, 1906.

Kingston, R. I., June 30, 1905.

I have the pleasure to present herewith, in compliance with the statute of the State and the Congressional act of March 2, 1887, the Report of the Director of the Rhode Island Agricultural Experiment Station for the year ending June 30, 1905.

Respectfully submitted,

For the Board of Managers,

CHARLES DEAN KIMBALL,

President.

AGRICULTURAL EXPERIMENT STATION

OF THE

RHODE ISLAND COLLEGE OF AGRICULTURE AND MECHANIC ARTS.

KINGSTON, R. I., June 30, 1905.

HON. CHARLES DEAN KIMBALL,
President, Board of Managers.

SIR:—I have the honor to transmit herewith the Eighteenth Annual Report of the Rhode Island Agricultural Experiment Station for the year ending June 30, 1905.

Respectfully yours,

H. J. WHEELER,
Director.

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DIRECTOR'S REPORT.

REPORT OF THE DIRECTOR.

Kingston, R. I., Aug. 23, 1905.

To Honorable Charles Dean Kimball, President of the Board of Managers of the Rhode Island College of Agriculture and Mechanic Arts.

Sir:—It gives me pleasure to report in detail concerning the work of the Experiment Station during the year ending June 30, 1905.

Division of Animal Husbandry.

During the the past year Dr. Cooper Curtice, in charge of the work in animal husbandry, has continued the experiments already begun in incubation, brooding, and in the feeding of young chicks. In addition to this work the experiments with turkeys have been continued for the purpose of learning, if possible, how the "blackhead" disease of the turkey (infectious *Entero-hepatitis*, Smith) is transmitted, and how it can possibly be controlled. It will be remembered that several years ago Dr. Theobald Smith, then in the employ of the Bureau of Animal Industry of the United States Department of Agriculture, working in response to the suggestion of and in co-operation with this Station, discovered the cause of the disease to be a minute animal parasite, the presence of which causes an inflammation and an enlargement of the cæca and also a peculiar and very characteristic appearance of the liver. Later Doctor Moore, of the same Bureau of the Department, discovered that the disease could probably be transmitted from one turkey to another through the fæces. At this stage the investigations were dropped until they were resumed again by this Station in the spring of 1902. After consulting with Doctor Smith, who was considered the best expert upon the subject of the disease, Doctor Curtice concluded that probably it could not be transmitted through the egg, and hence if other sources of contamination could be avoided it might be possible to obtain healthy birds from eggs that had been laid even by animals that were themselves diseased. With this idea in mind it was thought that if the young turkeys were reared upon land where no turkeys had been kept for several years, even though the eggs were hatched by ordinary hens and the young poults were allowed to remain with them, that there would be no danger of contagion. The experiments of that year showed, however, most conclusively, that the disease was either transmitted to the young turkey through the egg or else by the ordinary fowl or other forms of animal life which were to be found upon the Station grounds. The following spring unsuccessful attempts were made to obtain turkey eggs in considerable quantity from points in both Virginia and North Carolina, where the disease was said not to prevail. Owing to the failure of these attempts it was decided to buy some old turkeys and produce the eggs upon the Station grounds. In pursuance of this plan two lots, consisting in each case of one tom and three hen turkeys, were procured from Balitmore, North Carolina, and from Virginia. In both cases it was said that the disease was unknown in the sections from which the birds came. These two lots of turkeys were put into enclosures where no fowl of any description had been kept for many months and where it was hoped that the disease would not be acquired. During the following summer an ordinary hen in the Station poultry plant died of a disease that appeared in all particulars to be identical with the blackhead disease of the turkey. This was of special interest in view of the fact that during the preceding winter one of the turkeys from North Carolina had died of the blackhead disease.

Half of the eggs from each lot of turkeys were placed under hens and in incubators, while the others were left to be hatched by the old birds and to roam with them subsequently in the enclosures in which they were confined.

The young turkeys which had been hatched in the incubators and those from eggs that were placed at first under hens and finally in incubators, all of which had been brooded artificially where the chances of infection from ordinary fowl were reduced to a minimum, succeeded far better than the others even from the outset, notwithstanding that the food was the same in each case. So far as concerned the environment and the danger of contamination from the poultry plant, there was practically no difference between the pens where the old turkeys reared their young and those where the animals that were artificially hatched and brooded were kept. The disease appeared at an early stage in the birds that had been hatched by the old hen turkeys, and the total mortality was great; but in the case of the birds that were kept for a time in inside enclosures the time of infection was much delayed, the total losses by the disease were much lessened, and the animals appeared in general to be in better condition. In some cases as high as 80 per cent. of the entire lot was carried through to Thanksgiving time. In brief, the evidence obtained was to the effect that the infection was brought about after the birds were placed in the outside pens, but whether it came from the old turkeys, from the ordinary fowl in the adjacent poultry yard, or from other forms of animal life, it was impossible to determine in that season. It seemed possible that the sparrows which flew back and forth from the poultry yard to the turkey pens might have carried the infection, or possibly earthworms that might burrow under the netting which separated the yards. At all events it seemed to be of vital consequence to determine just how the disease is acquired and what are the hosts which convey it to the young turkeys.

In order to throw more definite light upon this point plans were made to grow some more turkeys in the poultry yards in the spring of 1905, placing some upon the ground immediately, and holding others away from the soil and the outside pens for several weeks. In addition some turkey eggs which had been placed under hens for a time were disinfected and the hatching was finished in incubators. These were brooded in houses where the chances of infection had been reduced to a minimum by disinfection, and after the birds were sufficiently old they were placed in some pens in a piece of forest land remote from any poultry plant. Already at the time of rendering this report the birds which were left upon the grounds of the Experiment Station have died in large numbers of the blackhead disease, and even though those in the forest are many of them equally as old, none have as yet been lost by the disease.

It must be realized that the solution of the problem of the sources of infection and the discovery of the various possible hosts of the disease organism will be time-consuming, and that it may take many seasons to accomplish the purpose sought. The slowness with which such an investigation must be conducted is much greater than it would be if turkey eggs and consequently an abundance of young turkeys were available at all seasons of the year.

Thanks to the hearty co-operation of the Secretary and Assistant Secretary of Agriculture, an arrangement has been effected with the Bureau of Animal Industry of the United States Department of Agriculture by which the Bureau is to assist the Station during the coming fiscal year in connection with breeding experiments with turkeys for the purpose of controlling, if possible, the blackhead disease. For this work it is hoped to obtain wild turkeys from Florida, Virginia, and elsewhere, and to cross these perhaps among themselves and upon some of the existing breeds of domestic turkeys. At the same time it is planned, if possible, to try and increase the egg-laying capacity and to produce a breed or breeds better adapted for the production of birds of the size of quail and partridges and of birds better suited to the Thanksgiving market than some of the present domestic breeds. It is hoped that when this work is once entered upon, the means will be obtained from the Department of Agriculture for a continuation of the co-operation in future years.

So far as concerns the work of the Division of Animal Husbandry of the Station, it is desirable that some arrangement should be perfected with the College whereby a more satisfactory subdivision of the demands upon Doctor Curtice can be provided. It is hoped such an arrangement can be made in the near future.

HORTICULTURAL DIVISION.

In the horticultural work during the past year Professor Card has been ably assisted by Mr. M. A. Blake, a graduate of the Massachusetts Agricultural College. During the year each has devoted a part of his time to the work of the College.

The experiments for the purpose of securing, if possible, a more hardy bean have been continued, and also those in Indian corn selection.

The experiments in the breeding of strawberries are making very good progress, and several promising new varieties have been produced. Some of the best of these will be multiplied as rapidly as possible and distributed for trial in different sections of the State.

The attempts to obtain crosses of the raspberry which will render it possible to materially prolong the season for that fruit are still being continued, though not with as great prospect of immediate results as the experiments in the crossing of strawberries.

In consequence of little injury to the plants during the past winter, the experiments in clover selection are more promising than last year. The casual visitor is impressed at once with the great differences that exist in the character of the individual plants. Some are early, some medium, and some late; others stand erect and have abundant leaves, while others produce stems which bear few leaves. In fact one would have difficulty in finding greater individuality in the human family than that which exists in the red clover plants produced from the seed now offered in the market.

The experiments in progress with the cauliflower the present season are of striking interest. Two lots are manured and being treated alike in every particular, excepting that one of the lots is being grown under a cloth cover similar to the ones that have been employed in

Connecticut in experiments with tobacco. The results of such an experiment depend largely upon the season, but during the present summer the cloth cover is making a great difference in the rapidity of the growth and in the degree of freedom from insect injury. The final results obtained will be embodied in a bulletin, or they will be given in a later report of the Horticulturist.

Owing to more or less injury to the blackberry bushes during the past winter, the experiments in interpollination are not in a fully satisfactory condition at present.

The two new rotations of market garden crops, one manured with stable manure and the other by means of chemical manures and cover crops, promise to be of increasing interest with the advance of time, but it is as yet much too early to form an opinion concerning their relative merits.

A new line of work has just been planned in this division, namely, that of testing various mixtures of grasses for lawns, golf links, and polo grounds. Accompanying it are trials of the effect of various chemical manures upon the kinds and the growth of the various grasses. It is hoped that these experiments will ultimately prove of material interest and value to the people of the State.

As opportunity offers the study of methods for the control of the apple-maggot is being continued.

It is hoped that this division will undertake some experimental work with the peach, for the purpose of producing, if possible, a variety that will withstand the extremes of climate which are characteristic of this State. There are said to be many isolated seedlings in the State which bear yearly and which are of fairly good quality. These might well serve as the basis for the steps at improvement, and it is hoped that persons having knowledge of such trees will call the attention of Professor Card to them without delay.

Now that the State has made provision for the construction of a new greenhouse, it is hoped that the federal appropriations for the Station may be increased sufficiently to allow of experimental work under glass, so that something can be done for this industry which the Station has had to practically neglect owing to the lack of means and to the want of a suitable house for such work.

DIVISION OF AGRONOMY.

The Division of Agronomy is continuing the experiments with crop rotations embracing a three-year, four-year, three five-year, a six-year, and a seven-year rotation. In brief, the object of this work is to learn the best and most economical means of renovating and subsequently maintaining the fertility of the neglected and more or less exhausted soils of the State, particularly where there is little stable manure available, and where it is impracticable or too expensive to undertake such renovation by its use. In connection with this experiment three check plots are used, one of which receives the full amounts of manures used in certain of the rotations, one receives two-thirds of the full application, and another one-third of that amount. In this way it is hoped to prevent if possible the use of materially larger amounts of manures than are actually required.

In grass culture one set of plots is devoted to an experiment for the purpose of learning the most economical amount of nitrogenous manure to use per acre where the entire dependence is placed upon chemical manures and where sufficient amounts of all of the other manurial substances are present in the soil. In a similar manner a set of plots is devoted to ascertaining the most economical amounts of acid phosphate to use, and another to finding out what are the most profitable amounts of muriate of potash to employ per acre. In all of these cases the results are for guidance in the treatment of land which receives no stable manure, though incidentally they are furnishing valuable hints as to the manures that should be used in supplementing the ordinary stable manures.

A set of experiments is in progress for the purpose of learning, if possible, whether it is best to use acid phosphate, finely ground bone, basic slag meal, or Peruvian guano as a source of phosphoric acid for the top-dressing of grass-lands. Similar experiments are also in progress for the purpose of comparing the relative efficiency of the phosphoric acid in finely ground bone meal, acid phosphate, and Peruvian guano. This is being conducted with the cruciferous plants such as beets and turnips, which are in great need of easily assimilable phosphoric acid and which may fail entirely for lack of it on land where redtop and millet will make a good growth.

In connection with alfalfa, trials are being made of the efficiency of nitro-culture, of frequent cutting during the first year, of drill culture, of broadcasting, and of seeding with oats, rye, and timothy.

There are four plots of land upon the Station farm, one of which has now become slightly alkaline (the opposite of acid), and the three others are of varying degrees of acidity. Upon these the various legumes that are of agricultural importance are being tested this season to learn the effect of the varying soil conditions upon their growth. In this connection it is of striking interest to see the difference in the influence of these conditions upon the growth of plants that are botanically closely related. For example, certain of the lupines thrive well upon very acid soil, while others are much more subject to injury by the same conditions. The beans also exhibit marked differences in this particular, for the velvet bean and the dwarf lima bean thrive better upon quite acid soil than where it has been rendered alkaline, while on the contrary Golden Wax and certain of the other string beans fail almost utterly upon the quite acid soil. Still other beans, such as the Horticultural pole bean, seem to stand midway between the two extremes as concerns the influence of these conditions.

The study of the after-effect of nine different kinds of phosphatic manures is being continued, using redtop as the plant to be grown, upon the twenty plots involved in the experiment. Already the striking ability of the redtop to secure its supply of phosphoric acid from materials which are of but slight use to plants of the beet, turnip, and cabbage family has been most plainly demonstrated. Indeed, so far as getting phosphoric acid is concerned, the redtop seems to be a scavenger among plants.

The experiment in grass culture with chemical manures is being continued on the same land, and also the experiment in continuous Indian corn culture by the use of chemical manures, both with and without cover crops and with and without the aid of underdraining.

By way of variety-testing, trials are being made of a large number of varieties of potatoes from Europe and from various parts of the United States, with the hope of finding varieties well adapted to this State and of securing kinds that will resist the blight better than those that are being grown at present. In addition trials are being made of a large number of different varieties of both the soy bean and the southern cow-pea.

A considerable quantity of the bean *Phaseolus mungo radiatus* is being grown for distribution next season to those who may desire to make a trial of it. It yields heavy crops, is easily grown, it ripens its seed perfectly in this climate, and on account of its ability to gather nitrogen from the air it can be grown with a minimum expenditure for manure. If ground and fed to fowl or other farm animals it may be a means of materially lessening the expenditure for the highly concentrated feeding-stuffs and prove an aid in maintaining the condition of Rhode Island farms. At least it gives promise of being worthy of a trial by some of the farmers of the State, under their own conditions.

This season the Station is testing a large number of varieties of Indian corn in co-operation with the Bureau of Plant Industry of the U. S. Department of Agriculture, to see if any of the early varieties under trial are especially adapted to the needs of this State.

In addition to the experiments at the Station, arrangements were made a few years ago for the use of one-fifth of an acre of land at West Kingston, where it had been difficult to maintain a stand of good grass for more than one or two years. This land was plowed, limed, manured, and reseeded to grass, and is being top-dressed annually to see if by this procedure the land can be made to yield a profit. These results will be published later, after the experiment has been continued sufficiently long so that satisfactory conclusions can be drawn concerning it.

POT AND WATER-CULTURE EXPERIMENTS.

In addition to a limited number of pot experiments which were being conducted at the Station, arrangements were made during the winter of 1904 and 1905 by which the Bureau of Soils of the U. S. Department of Agriculture was to assist the Station in connection with its soda investigations and at the same time make a trial of a new method of pot culture devised by the Bureau for ascertaining the deficiencies of soils. In addition to the pot experiments, water-culture experiments are also being conducted for the purpose of throwing additional light upon the reason for the unproductiveness of certain soils.

CHEMICAL INVESTIGATIONS IN THE LABORATORY.

In addition to the inspection and the analysis of commercial fertilizers and feeding-stuffs, the Station has made a careful study of some of the proposed chemical methods of ascertaining the requirements of soil for phosphoric acid, and a paper upon the results of this work may be found embodied in this report.

From time to time, as opportunity has presented itself, a further study has been made for the purpose of learning, if possible, if there are certain specific poisonous substances, not necessarily acid themselves, which are present in our acid soil. Some of the results of these and related observations are included in this report, and others will be presented in a later publication.

The chemical division of the Station has also been actively engaged, in co-operation with the Bureau of Soils of the United States Department of Agriculture, in making chemical examinations of crops grown with the aid of different amounts of potassium and sodium salts, in order to ascertain the probable effect which they may have exerted, not only upon the plants, but also upon the soils themselves. This co-operation has also included a study of the toxic substances of the soil as shown by a method of pot culture devised by the Bureau for studying soil requirements.

In addition to the inspection and investigation work of the chemical division, it has been called upon to make a considerable number of analyses for the other divisions of the Station.

CO-OPERATIVE WORK WITH BUREAUS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

A special feature of the work of the Station during the summer of 1905 is the co-operative work with the various Bureaus of the United States Department of Agriculture.

The work in connection with the Bureau of Plant Industry was undertaken at the solicitation of the Bureau, and consists in making a trial of a large number of early varieties of Indian corn. In order to do this work without interference with plans for the land which had already been made, it became necessary to hire land on a farm adjoining the Station. The Station furnishes everything needed in this work excepting the seed corn.

During the spring of 1905 the Director of the Station wrote to the Department of Agriculture in Washington to see if aid could not be extended to the Station in its experiments in connection with the "blackhead" disease of turkeys. Leading out of this, arrangements have since been perfected by which the Bureau of Animal Industry is to render aid in breeding experiments with turkeys for the purpose, if possible, of controlling the "blackhead" disease. The aid to be extended the Station during the next fiscal year is limited to the amount of $2,150.

It is hoped to secure wild turkeys from Virginia, Florida, and elsewhere, and make crosses of these with various domestic breeds of turkeys, and possibly to cross them among themselves. It is hoped that in this way a more hardy breed may be developed, and that possibly birds can be secured that will be especially adapted for producing turkeys of quail and partridge sizes. It is not at all impossible that something can be done by way of raising the egg-laying capacity of turkeys and thereby increasing their prospective money-producing capabilities.

In response to an invitation, sent at the same time to the Directors of several other experiment stations, the Director went to Washington just at the opening of the new year for the purpose of a conference with the Chief of the Bureau of Soils concerning co-operative soil investigations with this Station. According to the plan proposed the Station was to furnish certain facilities for the work but was not to have the direction of any part of it, though it was to be at liberty to offer suggestions to the Chief of the Bureau. After careful consideration of the matter the Board of Managers authorized the Director of the Station to decline the proposition. The work which it was proposed to undertake was the testing at the Station of methods of making pot tests of soils and a study of supposed toxic substances which the soils might contain.

Somewhat later a request was made to the Department of Agriculture for aid in connection with the investigations which had been in progress at the Station since 1894 concerning the agricultural value of common salt and other sodium compounds and their effect upon the soil and the crop. In response to this request the Chief of the Bureau of Soils was detailed to come to Kingston for a conference concerning the matter. As a result of this conference an arrangement was perfected by which the Bureau was to extend the desired aid for the coming year, and at the same time have the opportunity of carrying out the line of experiments outlined in the previous conference in Washington.

LIBRARY.

During the year the volume and efficiency of the library have been much increased by the addition of a considerable number of individual volumes and by the binding of the current scientific periodicals. It is hoped that during the coming year the files of the publications of the United States Department of Agriculture may be completed in so far as possible, and that these may be bound for more convenient reference.

BUILDINGS AND REPAIRS.

Under the rulings of the authorities in Washington all expenditures for roads, the improvement of grounds, for fencing, plumbing, gas piping, water piping, and for repairs to buildings must be scheduled under the heading "Buildings and Repairs," and the sum that can be expended annually for all of these purposes is extremely limited in amount. For this reason, particularly in view of the poultry experiments and the consequent demands for fencing and buildings which it entails, it became necessary to ask for an appropriation of $500 from the State for repairs to the poultry buildings and yards. This appropriation, which was made at the last session of the General Assembly, will be of material aid in putting the poultry plant of the Experiment Station in a suitable and appropriate condition.

PUBLICATIONS.

During the year ending June 30, 1905, the following publications have been issued:

The Seventeenth Annual Report. pp. 161 to 289.

Bulletin No. 102, "Commercial Fertilizers." 14 pp.

Bulletin No. 103, "Experiments in Grass Culture." 30 pp.

Bulletin No. 104, "Plant Peculiarities as shown by the Influence of Sodium Salts." 47 pp.

Bulletin No. 105, "Commercial Feeding Stuffs." 16 pp.

Bulletin No. 106, "Concerning the Agricultural Value of Sodium Salts." 46 pp.

Bulletin No. 107, "Soil Treatment in Greenhouse Culture." 13 pp.

The demand for the Station publications has continued to steadily increase, and many letters have been received during the year thanking the Station for the aid which its publications have afforded. In several instances the writers have attributed their ability to succeed upon the land which they are tilling solely to the information relating to soils and to other matters which the Station has issued.

BULLETINS AND REPORTS OF THE STATION DESIRED.

It is most urgently requested that persons who have any of the earlier bulletins and annual reports of the Station which they do not desire to preserve will have the kindness to return them to the Station and thus aid in meeting the innumerable and continuous calls from libraries. Similar calls are received daily from students and farmers in all parts of the country, but such demands the Station has not been able to meet for a long time. In cases where such bulletins and reports are forwarded to the Station the persons sending them will be reimbursed for the expense attendant thereon.

STATION STAFF.

In the course of the year which has just elapsed no changes have occurred in the personnel of the heads of divisions.

The position made vacant at the close of the preceding year by the resignation of Miss Ethel Chadwick was filled by the appointment of Miss Martha Vickery as stenographer and librarian. Before the close of the year she in turn severed her connection with the Station and the position is now being filled temporarily, pending more definite arrangements.

Shortly after the beginning of the year Mr. H. M. Soper resigned to accept a commercial position, and his place was filled the following November by the appointment of Mr. Matthew Steel, a graduate of the College of Agriculture and Mechanic Arts of New Mexico. Subsequent to his regular course of study Mr. Steel had taken the degree of M. Sc. from the same college, and he had filled for a time a position as "Scientific Aid" in the Office of Experiment Stations of the Department of Agriculture, Washington, D. C. In May, 1905, Mr. Steel was appointed "Expert" in the Bureau of Soils at Washington, though still engaged in work at this Station in co-operation with that Bureau.

During the year Mr. A. E. Stene was transferred to the Extension Department of the College and Mr. M. A. Blake, a graduate of the

Massachusetts Agricultural College, was engaged as assistant horticulturist. It is due Mr. Blake to say that he has taken up his work with unusual industry and has shown exceptional adaptability to the requirements of the position.

On April 1st, 1905, Mr. J. W. Kellogg, first assistant chemist at the Station, was appointed "Expert" in the Bureau of Soils of the United States Department of Agriculture, though he still continues his labors at the Station in connection with the co-operative work in which the Station and the Bureau of Soils are engaged.

It gives me great pleasure to acknowledge the cordial support of the heads of divisions of the Station, Professors Curtice and Card.

To my associate chemist, Dr. B. L. Hartwell; to Mr. G. E. Adams, assistant in agronomy; and to Miss Beulah A. Hoitt, stenographer and accountant, my thanks are especially due for the very efficient manner in which they have attended to the many and important details of the Station work which have been entrusted to their care, and which have many times, particularly in the case of Mr. Adams, necessitated working out of regular hours and under trying conditions.

Finally, it gives me pleasure to acknowledge the hearty support of the Board of Managers, which has been granted freely in connection with every plan that has been made to further the best interests of the agriculture of the State.

Respectfully submitted,

H. J. WHEELER,

Director.

HORTICULTURAL DIVISION.

REPORT OF THE HORTICULTURAL DIVISION.

F. W. CARD AND M. A. BLAKE.

APPLE-MAGGOT.

But little work was carried on with the apple-maggot in the season of 1904. Not many pupæ were readily available. The results were so unexpected, however, that it seems best to record them. The plan was to try the effect of tillage by placing pupæ in one frame in which the soil was stirred to a depth of two or three inches every week or ten days during the early part of the season. Others were placed in another frame in which the soil was left undisturbed. Fifteen pupæ were put in one large frame covered with wire netting in which the soil was kept stirred, and five were placed in each of three smaller frames in which the soil was left undisturbed. These pupæ were placed in the soil May 10th, being covered in all cases with about one-half inch of loose earth. These frames were watched during the time when the flies should have appeared, but none emerged, unless they escaped observation. This is so at variance with previous experience in watching the emergence of flies that we are wholly unable to account for it. So far as we are aware nothing in the handling of the pupæ would tend to prevent their development.

Observations made upon the fruit harvested from the College orchards during the fall and winter showed that apples from the old orchard, where hogs ran the year before, were comparatively free from maggots in 1904. Entire freedom could not be expected, even if the hogs had done their work perfectly, because this orchard is only a short distance removed from other trees in the younger orchard. The results, however, were sufficiently marked to show that pasturing the orchard with stock which will promptly destroy all windfalls is a satisfactory method of controlling this pest wherever orchards are sufficiently isolated to prevent the ready entrance of the flies from neighboring orchards where the pest abounds. Fruit from trees which overhung the fence and also from one or two trees just across a roadway from this old orchard was picked up and thrown inside where it could be eaten by the hogs, but some maggots may have escaped from this fruit before it was removed. Fruit from one tree bearing sweet apples, which stood by the fence, was somewhat injured. The Fall Pippins and winter apples were almost wholly free from injury.

Many varieties in the tilled orchard, such as Hubbardston, Grimes, Mother, and earlier kinds were badly injured. This orchard receives good tillage, and if that would prove a preventive, the fruit ought to be clear. Most of the windfalls were picked up during 1904, and hogs were again placed in the old orchard.

Several cases were observed during the winter where larvæ pupated in the cellar just at the surface of the apple. The pupæ remained in the exit hole, but standing out the greater part of their length from the surface of the apple.

APPLES—RESISTANCE TO WIND.

On September 8, 1904, an unusually severe wind-storm swept over this region, blowing off much of the fruit then on the trees. Observations were made upon a number of varieties as to their ability to remain on the trees in such a wind. A score was made on the scale of 1 to 10, 10 meaning that little or no fruit had fallen from the tree. This score, as recorded, is as follows:

R. I. Greening	8	Pomme Gris	7
Wagener	8	Swaar	9
Seek-no-further	7	Walbridge	9
Smith Cider	8.5	York Imperial	6
Winesap	10	Roxbury Russet	10
Mann	7.5	Canada Red	10

Tuft Baldwin	6	Rambo	8
Northwestern Greening	7.5	Genet	10
Palmer	7.5	Northern Spy	8
Yellow Bellflower	8	Missouri Pippin	9
Domine	8.5	Hubbardston	8
Ben Davis	10	Cooper Market	9
Grimes Golden	9.5	Lady	9
Mother	9	Pewaukee	7

BUSH-FRUITS.

After six years of work with bush-fruits on our Experiment Station land, the conclusion is forced upon us that the climatic conditions prevailing in that situation are decidedly unfavorable to the growth of bramble fruits. These conditions have caused a partial or complete failure of all our experiments. We have produced a number of seedlings grown from crosses, and a few of these have shown fairly promising results. A large number were ready to fruit this year, but were badly winter-killed. Some red raspberry seedlings, which were on College land on the hill, bore a satisfactory crop in 1904. These also promise well for 1905, but those on the plain have been badly winter-killed, as usual. This does not result from extreme temperatures. At no time during the past winter did the mercury reach 10° below zero, and in only a few cases as low as zero. In interior climates bush-fruits pass much lower temperatures practically unharmed. Perhaps it is the greater humidity caused by proximity to the ocean which causes more injury here.

The interpollination experiment with blackberries gave so little fruit in 1904 that no conclusions are warranted. The plot of Snyder produced only 5¼ boxes of fruit. The plot of Taylor produced only one box, while the mixed plot, made up of both varieties, produced 2¼ boxes. This difference was really a question of difference in hardiness between the two varieties. Only two or three plants of the Taylor variety bore any fruit whatever. The prospects for 1905 are no better, since the greater proportion of these plants were killed to the ground during the winter. The work in selection, designed to determine whether propagating from plants which gave the largest yield would tend to develop a more productive strain, has met with the same fate as the other experiments. Most of the plants have been so weakened by winter injury that no yields of value could be obtained and no plants for future work. The experiment has, therefore, had to be abandoned. In some cases attempts have been made to prevent this winter-killing by laying down and covering the plants, but that did not prove satisfactory under our conditions, although it is a method frequently used in colder climates.

CORN SELECTION.

The seed of corn saved from corn selection experiments in 1903 was not well ripened when frosts appeared, and did not germinate strongly in the spring of 1904. It was planted June 3d, but the most available place was a portion of the experimental grounds which had been under tillage for several years and did not, therefore, offer such desirable conditions as sod ground gives. Although treated with commercial fertilizers and given an additional dressing of nitrate of soda, the growth was poor and weak and the corn was not well matured at harvesting time, giving an uneven stand again in 1905. The seed planted in 1904 was from the upper ear lot of the previous year, which was classified as carrying eight ears per stalk. Anything which showed a single kernel was called an ear, and some were, therefore, very poorly developed. A photograph of these stalks appears in the annual report of 1904. As there noted, selection from lower ears has been abandoned.

When harvested in the fall a count of the ears showed the following conditions:

Number of 1-ear stalks	222
Number of 2-ear stalks	291
Number of 3-ear stalks	101
Number of 4-ear stalks	8

The corn was so immature when harvested, owing, in part, to the unusually early and severe freeze, that no attempt was made to husk and weigh the ears from the different classes. A high wind in the latter part of the summer broke down many of the stalks, which failed to straighten up again. These results show a decided reduction in the number of ears per stalk over those produced in 1903, and thereby serve to enforce a good lesson. This lesson is that while such things as selecting seed from the most productive parent plants may be important, they are of less moment than attention to the well-known cultural conditions, such as sound mature seed, planting in season, on good soil, at the proper point in the rotation, and giving good culture to the plants. These are things which everybody knows to be important but which we are very likely to neglect.

A MARKET-GARDEN ROTATION.

The object of this experiment is to determine whether it is possible to grow market-garden crops successfully without stable manure, by means of planning a rotation whereby cover-crops can be introduced from time to time for the purpose of maintaining humus in the soil. A four-year rotation was planned for this experiment, and begun in 1904. As outlined, the rotation is to be as follows:

1st year. Corn (Cory), followed by beans.
Beans, followed by corn (Crosby).

In both of these second crops clover is to be sown at the last cultivation, to afford a cover-crop during the winter and to add vegetable matter to be turned under the following spring. The object of dividing the plot and beginning with both corn and beans is to provide a better succession.

2d year. Tomatoes, followed by rye, the clover sown the fall before being allowed to grow in the spring until necessary to turn it under to plant the tomatoes. This late-planted crop affords an opportunity for a good growth of clover.

3d year. Potatoes (extra early), followed by cabbage.
Early cabbage, followed by carrots.

4th year. Onions.
Spinach, followed by celery, followed by spinach again, or
Transplanted lettuce, followed by celery.

RYE AS A COVER-CROP.

Two plots, each containing 1-10 acre, being 204 feet long by 21 feet 4 inches wide, were measured off at the west end of the plain for this experiment. The west plot, the northwest corner of which is at an iron stake driven in the ground at the angle where the highway crosses the plain, is to be treated with stable manure. The east plot, which is separated from the other by a path 4 feet wide, is to be treated with chemicals and cover-crops. No cover-crops are to be used on the plot which receives stable manure. The amount of fertilizer decided upon to use is as follows:

On the stable-manure plot, 1 cord, being at the rate of 10 cords per acre, is used. On the fertilizer plot chemicals are applied as follows:

	Per plot.	Rate per acre.
Nitrate of soda	40 lbs.	400 lbs.
Dried blood	30 "	300 "
Acid phosphate	100 "	1,000 "
Muriate of potash	30 "	300 "

With most crops the nitrate of soda is to be used in different applications as needed, the other chemicals being all applied at once in the spring. For tomatoes, which appear in the second year of the rotation, all the nitrate of soda is to be applied with the other fertilizers.

In 1904 the fertilizers required and the manure were put upon these plots May 4th and 5th. Both plots were also limed at the rate of one ton per acre. The plots were planted to corn and beans as outlined, May 6th, with six rows three feet apart on each plot. The corn was planted three kernels in a hill, with hills two feet apart. The beans were planted in drills three feet apart, with seeds about three inches apart in the drill. A second application of nitrate of soda was made May 21st.

A note made July 5th states that corn on the plot treated with stable manure was much in advance of that on the one treated with chemicals, being nearly double in size and much more vigorous. Beans were also much more vigorous on this plot, the foliage being darker in color. The beans on both plots began to bloom at about the same time and with apparently an equal number of blooms. Corn appeared to be suckering more where stable-manure was used.

Crosby corn was planted between the beans on both plots July 11th. Beans were planted between the corn rows on both plots July 26th.

The harvesting of string-beans began on both plots July 14th and continued until August 19th. No apparent difference in time of maturing can be detected from a study of the amounts and dates of the different pickings. The total weight harvested from the plot receiving chemical manures was 221 pounds, 1 ounce; the total weight from the stable-manured plot was 347 pounds, 1 ounce.

The corn grown from the first planting was all harvested August 9th. One large ear and two small ears on the plot with chemicals had been injured by fowls, the weight of the remaining cobs and husks being 9 ounces. Nineteen large ears and four small ones had been injured in the plot with stable manure, the weight of remaining cobs and husks being 6 pounds, 8 ounces. Adding these partial weights to the weights of uninjured ears gathered gives a yield of 10 pounds, 6 ounces, from the plot which received chemicals and 124 pounds from the plot which received stable manure. The stalks from this first crop of corn were cut August 17th, the growth being good on both plots. Crimson clover was sown in the chemical plot August 19th. On the night of September 22d an unusually hard freeze occurred, the temperature falling to 24° Fahrenheit, with the result that both the corn and the beans were frozen. The beans were picked and weighed the following day, the yields being as follows:

From the fertilizer plot	**33 lbs. 8 oz.**
From the manure plot	**25 lbs. 3 oz.**

These beans were planted between the rows of earlier corn on July 26th, and had made considerable growth before the corn was cut on August 17th. The corn on the manured plot was heavier than on the one receiving chemicals, therefore these beans were somewhat more shaded on that plot and grew more spindling. For this reason they were probably in poorer condition to stand the direct sunlight when the corn was removed than those on the plot manured with chemicals.

At the time of this freeze the second crop of corn had not reached cooking condition, therefore this part of the experiment proved a failure and no records were made. Ordinarily, sweet corn can be harvested for table use until much later than this.

A fair amount of clover lived through the winter on the plot which received chemicals, there being a reasonably good growth to turn under when the land was plowed for tomatoes, which was done June 7th, the plants being set June 9th.

SOIL STERILIZATION.

Growers of market-garden crops under glass meet with serious difficulty from fungous diseases which gain lodgment in the soil. This is particularly true in the growing of greenhouse lettuce. To avoid this trouble, growers have usually incurred heavy expense in replacing the soil of the beds with fresh garden soil at frequent intervals. Experiments and practical trials have been made in sterilizing the soil remaining in the beds after one season's work, in the hope of escaping the expense of putting in new soil, while at the same time destroying the diseases which cause trouble. When thoroughly done this practice seems to be uniformly effective in ridding the soil of diseases, but the growth of succeeding crops has not been so uniformly satisfactory. As one lettuce grower puts it, sterilizing seems to destroy the "life" of the soil so that plants do not make the rapid, vigorous growth which gardeners demand that they shall make.

Two possible explanations of these unfavorable results suggest themselves. One is that as the sterilization is commonly done steam-pipes are placed underneath the soil, the steam turned on until the soil is thoroughly "cooked," as the gardeners say, when it is immediately shovelled over, to get at the pipes, which are moved to a new location. It has been thought that this handling of the soil while still hot and wet from the steam which has been forced into it might tend to injure the physical condition, causing it to become puddled, thereby producing unfavorable results.

Another possible explanation of the unfavorable results is that sterilization not only destroys the disease germs which are present in the soil, but it seems likewise to destroy beneficial soil organisms. We are only just beginning to realize the importance of these organisms in the growth of plants, but it is certain that they play a prominent part in plant development. The practical gardener may, therefore, be stating the exact scientific truth when he says that sterilizing destroys the life of the soil. One instance in the practical management of greenhouse lettuce seems to point in this direction. An establishment in the city of Providence procured a sterilizing apparatus and tried it for a time, getting such results as have been mentioned, namely; freedom from disease but unsatisfactory growth. The apparatus was then sold to another firm outside the city. This firm was particularly pleased with the results which were obtained from its use. Their method, however, was somewhat different from that followed by the first firm. They placed the pipes very near the surface and aimed to sterilize only a shallow layer of the surface soil. In this way the spores of the different lettuce diseases were destroyed in the surface soil, where alone they can come in contact with the plant in such a way as to cause injury. On the other hand the heat probably did not penetrate deeply enough to destroy the beneficial organisms of the soil underneath; and consequently these organisms were able to continue their work in much of the soil which was permeated by the roots of the plants.

In the hope of securing some light on this problem, an experiment was begun in 1903, in which lettuce and radishes were grown in large pots. The soil used was made up of three parts of garden soil which was quite rich in decaying vegetable matter, mixed with one part of cow manure. After a thorough mixing this was sifted through a coarse sieve and steamed for one hour and forty-five minutes to sterilize it. This steaming was done in a tight box, the soil being placed in trays with wire bottoms to enable the steam to thoroughly permeate the whole mass. While still hot, enough soil was taken out and worked over to fill four pots, the remainder being allowed to cool before being handled. Four other pots were filled with unsterilized soil of the same kind. Those pots in which sterilized soil was placed were themselves sterilized. The experiment consisted of the following series, four pots being treated in each of the ways indicated:

1.—Soil unsterilized.
2.—Soil sterilized and handled while hot.
3.—Soil sterilized but not handled till cold and dry.
4.—Soil sterilized, handled cold, and later sprinkled with garden soil.
5.—Soil sterilized, handled cold, and nitrate of soda used.

On August 19th Deep Scarlet Turnip radish seed was planted in two of the pots in each series, Market Garden Private Stock lettuce being planted in the other pots. August 31st the pots in series No. 4 were sprinkled with soil from the College orchard. This was thought to be a fairly satisfactory garden soil, since the land among the trees had been previously used for garden crops for some time. On the same date nitrate of soda was applied to the pots in series No. 5. Other applications were made September 8th and September 17th. The first crop of radishes was harvested September 17th and the pots immediately replanted with the same variety.

The second crop was harvested October 27th. The number of plants and the weights obtained are shown in the following table:

		No. plants.	Weight, ounces.	Total plants.	Total weight
Unsterilized	1st crop	22	$10\frac{6}{16}$	..	..
	2nd crop	20	6	42	$16\frac{9}{16}$
Sterilized, handled while hot	1st crop	17	4	..	..
	2nd crop	23	$7\frac{3}{4}$	40	$11\frac{3}{4}$
Sterilized, handled cold	1st crop	28	$7\frac{5}{8}$	..	..
	2nd crop	24	$7\frac{3}{4}$	52	$15\frac{3}{8}$
Sterilized, sprinkled with soil	1st crop	17	$2\frac{1}{4}$	..	..
	2nd crop	24	$3\frac{7}{8}$	41	$6\frac{1}{8}$
Sterilized, plus nitrate of soda	1st crop	20	$4\frac{5}{8}$	..	..
	2nd crop	18	$3\frac{3}{4}$	38	$8\frac{3}{8}$

This shows the order of yield to have been as follows:

First, unsterilized soil; second, soil sterilized but not handled until cool and dry; third, soil sterilized and handled while hot; fourth, soil sterilized, with nitrate of soda added; fifth, soil sterilized and sprinkled with garden soil.

The lettuce was thinned to four plants on September 17th. In some cases not that many plants remained at the close of the experiment. The plants were harvested November 9th. Those in the unsterilized soil had done the best. The others were slightly frozen or diseased. A number of weeds had appeared in the unsterilized soil but none in the rest.

The weights harvested were as follows:

	No. of plants.	Weight.
Unsterilized soil	6	19 ozs.
Sterilized soil, handled hot	3	$6\frac{3}{8}$ ozs.
Sterilized, handled cold and dry	4	$8\frac{5}{8}$ ozs.

As with the radishes, this shows the best results to have been obtained from the unsterilized soil.

These experiments were continued in the same manner in 1904.

Pressure of other work prevented their being started as early as would have been desirable. Absence of greenhouse facilities made it impossible that they should be carried on during the winter, when such work is usually done. Deacon lettuce and Crimson Giant Globe radish were sown in all the pots July 11, 1904. August 5th a few of the radishes had come to maturity. None were of salable size in the unsterilized soil. A single one had matured in the sterilized soil which was handled while hot, also in that which had been sprinkled with garden soil. Radishes in the pots to which nitrate of soda was added appeared to be very much better than in any of the others. Though the tops were not quite as large, they were apparently in advance of the others in maturity. There appeared to be a tendency toward a large growth of top where garden soil had been sprinkled on the surface. These radishes were inferior in quality. The yields obtained were as follows:

	Total Weight.	Weight of leaves.	Weight of roots.
Unsterilized soil................	508.90 grams	188.77 grams	320.13 grams.
Sterilized, handled while hot.....	453.56 “	206.25 “	247.31 “
Sterilized, handled cold and dry..	384.00 “	197.1 “	186.90 “
Sterilized, sprinkled with garden soil........................	446.00 “	291.78 “	154.22 “
Sterilized, with nitrate of soda added......................	627.25 “	239.95 “	387.30 “

Arranged in order of greatest total weight, the different methods of treatment stand as follows: first, sterilized soil plus nitrate of soda; second, unsterilized; third, sterilized, handled hot; fourth, sterilized, sprinkled with garden soil; fifth, sterilized, handled cold and dry. The order of arrangement for greatest weight of roots is the same, with the exception of the last two, which change places, that sprinkled with garden soil having given the smallest weight of roots alone. Arranged in the order of early maturity, the series stands: first, sterilized soil plus nitrate of soda; second, sterilized soil sprinkled with garden soil and sterilized soil handled hot, which rank together; third, sterilized soil handled cold; fourth, unsterilized.

Notes made upon the lettuce August 5th show that the plants in the unsterilized soil had made a fair growth. That in the pots sprinkled with garden soil had made the poorest growth of any. All the others were doing fairly well. The plants were thinned to four in each pot after they had started, but in some cases a smaller number remained at the end. The lettuce was cut and weighed September 4, 1904. The outside leaves of the plants in the unsterilized soil were greener than any of the others. The outside leaves of those in the sterilized soil handled hot had turned brown. Seed did not germinate well in the nitrate of soda pots, so that these had to be resown a few days later than the others, which may have influenced the result somewhat.

The total weights harvested were as follows :

Unsterilized soil	681.7	grams.
Sterilized, handled hot	434.2	"
Sterilized, handled cold	443.7	"
Sterilized, sprinkled with garden soil	319.2	"
Sterilized, plus nitrate of soda	445.6	"

Arranged in order of greatest weight, therefore, the lettuce stands as follows: first, unsterilized soil; second, sterilized plus nitrate of soda; third, sterilized, handled cold; fourth, sterilized, handled hot; fifth, sterilized, sprinkled with garden soil.

The garden soil used in sprinkling these pots was taken from the same field as that used in 1903. After the results were obtained this soil was tested and found to be somewhat acid. This fact may account for the unfavorable results which apparently followed its use. The object of sprinkling the surface with fresh garden soil was to determine whether by this means the beneficial soil organisms which aid in plant growth might be reintroduced. If so, a grower could sterilize the soil of his greenhouse beds, then add a light covering of fresh soil, thereby destroying undesirable spores and organisms and at the same time securing the aid of helpful ones. Thus far our experiments seem, for some reason, to be very unfavorable to this line of action. The most important of these soil organisms are the ones which induce nitrification, that is, the process by which the nitrogen of stable-manure or other organic substances is changed into forms available for plants. It is only after having been worked over by bacteria that the major portion of the nitrogen of manure can be used in producing plant growth. It is therefore of great importance that these bacteria should be present in the soil. Nitrate of soda, on the other hand, furnishes nitrogen in a form immediately available. In the absence of soil organisms it is therefore reasonable that this material might be able to take their place so far as furnishing nitrogen is concerned. This explains its use in these experiments, and the results thus far seem favorable to such a practice.

TENT COVERING FOR VEGETABLES.

The experiments in growing vegetables under a tent were continued in 1904 with lettuce, celery and cauliflower.

Lettuce.

Lettuce showed the effect of being transplanted much less under the tent than outside. This is one of the marked advantages of the shade. Lettuce seems to grow faster underneath the tent than outside, up to the heading point, and is apparently more brittle and tender, but that outside makes more solid heads. Under the tent heads are loose and the plants run up to seed more quickly.

The weights at the time of harvesting were as follows:

Transplanted.

DATE.	Outside the Tent.		Inside the Tent.	
	No. of heads.	Weights.	No. of heads.	Weights.
Aug. 3	38	13 lbs. 6 ozs.	48	18 lbs. 14 ozs.
" 9	55	15 " 14 "	44	14 "
" 30	36	20 " 11 "	36	20 " 12 "
	129	49 lbs. 15 ozs.	128	53 lbs. 10 ozs.

Average weight per head of those outside—6.19 ozs.
Average weight per head of those inside—6.57 ozs.

Grown from Seed.

DATE.	Outside the Tent.		Inside the Tent.	
	No. of heads.	Weights.	No. of heads.	Weights.
Sept. 1	2	1 lb. 8 ozs.	..	
" 8	59	51 lbs. 14 "	62	37 lbs. 15 ozs.
	61	53 lbs. 6 ozs.	62	37 lbs. 15 ozs.

Average weight per head of those outside—14. ozs.
Average weight per head of those inside—9.8 ozs.

At harvesting time a head of lettuce from that grown inside and one from that grown outside were given to a number of different families for testing. Nearly all considered that grown outside better in quality. The heads were better, though no great difference in quality could be detected. Apparently that grown outside was equally tender and of slightly better flavor. That grown inside appeared to wilt a little more quickly. One family thought that the head grown inside was less bitter than the other.

Cauliflower.

As with lettuce, cauliflower plants showed less injury from transplanting under the tent than outside, and made a better growth throughout the season. The growth of leaves was much stronger and the plants stood noticeably higher than those outside.

The yields obtained were as follows:

Outside the Tent.		*Inside the Tent.*	
DATE.	**Weights.**	**DATE.**	**Weights.**
Sept. 26..............	25 lbs.	....	47 lbs. 2 ozs.
Oct. 6..............	15 " 2 "	....	46 "
" 17..............	6 " 4 "	....	17 " 6 "
	46 lbs. 6 ozs.	....	110 lbs. 8 ozs.

This shows a difference of 64 pounds 2 ounces in favor of that grown inside.

It will be noted that the average yield was somewhat retarded inside the tent, although the first cutting was larger than that outside. The shade of the tent also proves an advantage in keeping the heads white, since they are less likely to discolor if not tied up at just the proper time. In fact very little extra shade is needed under the tents. A still further advantage accrues from the fact that the tent protects the plants from the attacks of insects.

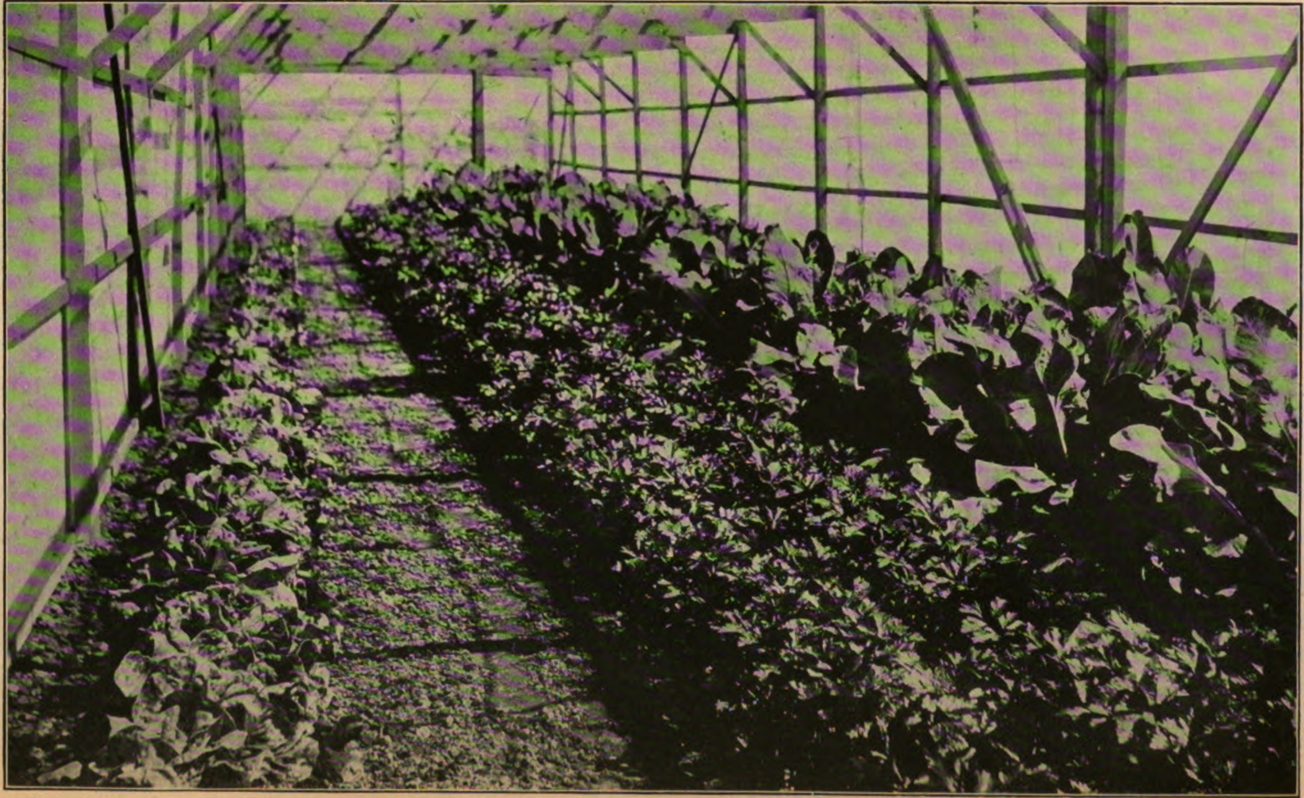

Fig. 1.—Shading Experiment. Vegetables inside the Tent

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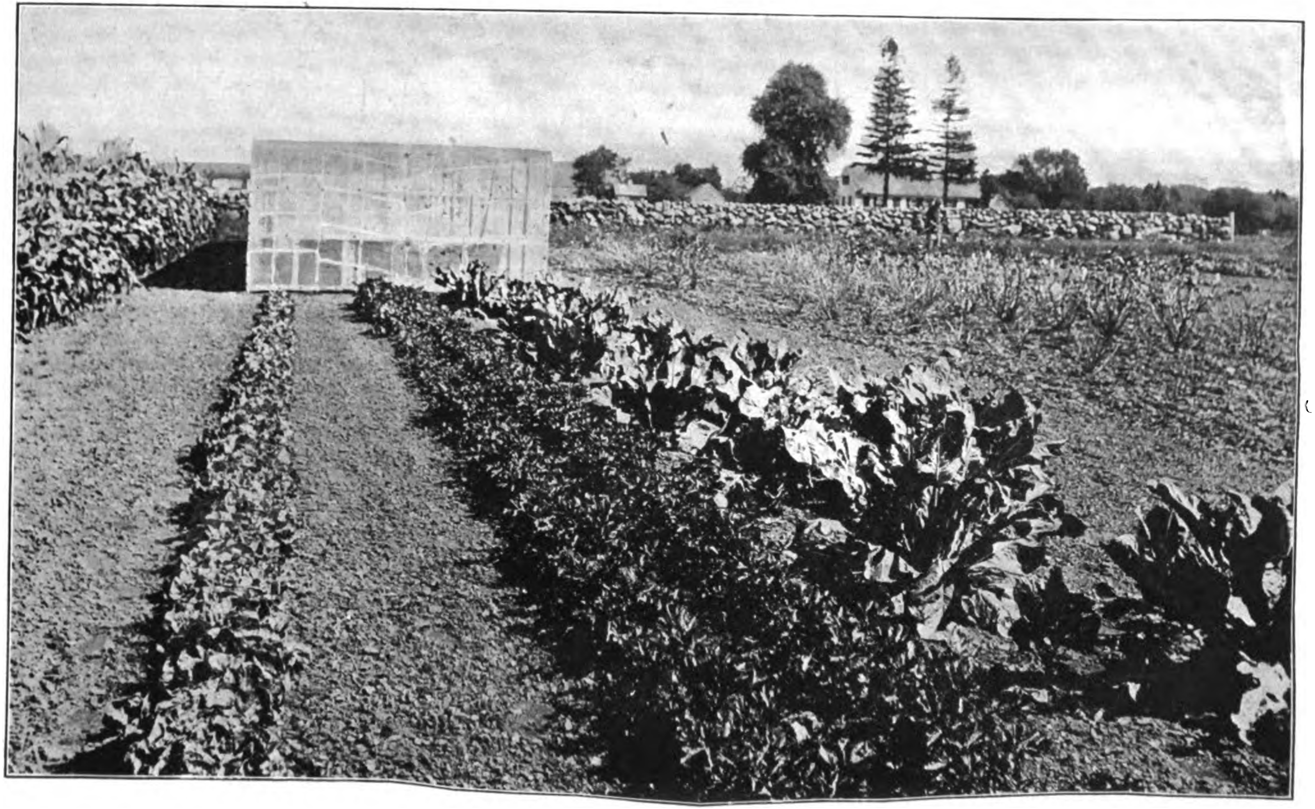

Fig. 2.—Shading Experiment. Vegetables outside the Tent.

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Celery.

A few plants of Golden Self-Blanching and a few of Fin de Siecle celery were set in the tent June 28th and June 29th, with an equal number outside. These were harvested November 7th. The roots were cut off and the plants weighed without further trimming. They were then washed and trimmed and weighed again.

The yields were as follows:

Golden Self-Blanching.

Grown outside, untrimmed	8 lbs.	
“ inside, “	10 “	14 ozs.
“ outside, trimmed and washed	2 “	7 “
“ inside, “ “ “	5 “	14 “

Fin de Siecle.

Grown outside, untrimmed	25 lbs.	
“ inside, “	23 “	6 ozs.
“ outside, trimmed and washed	7 “	10 “
“ inside, “ “ “	9 “	9 “

Additional plants were set both inside and outside on July 7th. These were also harvested November 7th, the yields being as follows:

Grown outside, untrimmed	92 lbs.	8 ozs.
“ inside, “	87 “	15 “
“ outside, trimmed and washed	40 “	6 “
“ inside, “ “ “	44 “	14 “

The yield of the entire crop, including both plantings, was as follows:

Grown outside, untrimmed	125 lbs.	8 ozs.
“ inside, “	122 “	3 “
“ outside, trimmed and washed	50 “	7 “
“ inside, “ “ “	60 “	5 “

It will be noted that in all cases there was a smaller percentage of waste from the celery grown under the tent than from that grown in the open. That grown inside was taller, and the leaves which were exposed above the earth with which it was banked were somewhat greener. The stalks appeared to be a little softer. That grown outside was shorter and more stocky in growth, with more waste leaves on the outside. During growth the plants under the tent appeared more healthy. Those on the outside showed considerable rust on the leaves. This was less noticeable on those growing inside.

Plants from both lots were given to different families for testing. All except one considered that grown outside to be of better quality.

Temperatures.

To determine the effect of the tent upon temperature, observations were made at different times during July and August. These temperatures were taken from hotbed thermometers placed in the soil. Toward the end of this period the one inside was partially shaded by the larger growth of cauliflower leaves, which probably made the differences greater than they otherwise would have been. As recorded these temperatures are as follows:

Date.	Hour.	Temperature.
July 13	11 A. M.	4° cooler in tent.
13	2:30 P. M.	8° " " "
14	8 A. M.	6° " " "
14	3 P. M.	6° " " "
15	7:30 A. M.	6° " " "
15	2:30 P. M.	3° " " "
16	10 A. M.	1° " " "
18	12 M.	4° " " "
19	8 A. M.	1° " " "
19	9:30 A. M.	5° " " "
20	10 A. M.	9° " " "
20	3:30 P. M.	6° " " "
26	10:30 A. M.	4° " " "
27	8 A. M.	2° " " "
27	4 P. M.	1° " " "
Aug. 1	10:30 A. M.	3° " " "
3	7:30 A. M.	6° " " "
4	1 P. M.	1° " " "

Date.	Hour.	Temperature.
Aug. 8	1 P. M.	3° cooler in tent.
11	8:15 A. M.	4° " " "
12	10 A. M.	4° " " "
15	7:15 A. M.	10° " " "
15	3:30 P. M.	10° " " "
17	7:45 A. M.	4° " " "
17	3:45 P. M.	6° " " "
18	1:15 P. M.	9° " " "
19	7:30 A. M.	12° " " "
19	9:30 A. M.	12° " " "
Average		5.36° " " "

Attempts were made to determine differences in humidity, if any existed, but with the instruments available no important difference could be discovered.

STRAWBERRY SEEDLINGS.

A large number of strawberry seedlings were in fruit in 1904. In order to keep a more intelligent record of their behavior a score-card was devised and used. A copy of this score-card is presented herewith:

STRAWBERRY

Variety...

SCALE-POINTS 10-Perfect

Plant

Vigor	Disease Resistance	Frost Resistance

Fruit

Productiveness	Size	Regularity
Appearance	Texture	Quality
Fragrance	Rot Resistance	

DESCRIPTION

Plant

Leaves	
Runners	Fruiting Stems
Bloom Season	Sex

Fruit

Form Flavor
Color Color of Flesh
Calyx Core
Seeds Position Size Color
Season First Heaviest Last
General Notes
Date...................... Observer

To simplify entering the records, the following key was devised and used:

Key.

Leaves

Number Size
n=numerous; f=few. l=large; sm=small; m=medium.

Height Color
t=tall; s=short. d=dark; lt=light.

Surface
r=rugose; gl=glossy; c=curled; w=wrinkled.

Runners

st=strong; w=weak; n=numerous; l=long; s=short; f=few.

Fruiting Stems

st=strong; w=weak; l=long; s=short.

Number of Fruits

n=numerous; f=few.

Bloom

Season
e=early; m=medium; l=late.

Sex
p=perfect; i=imperfect.

Size
l=large; sm=small; m=medium.

Form

i=irregular; reg=regular; cox=coxcombed; ang=angular; fl=flattened; s=short; l=long; r=round; c=conic; o=oblate; ob=oblong; ov=ovate; obt=obtuse.

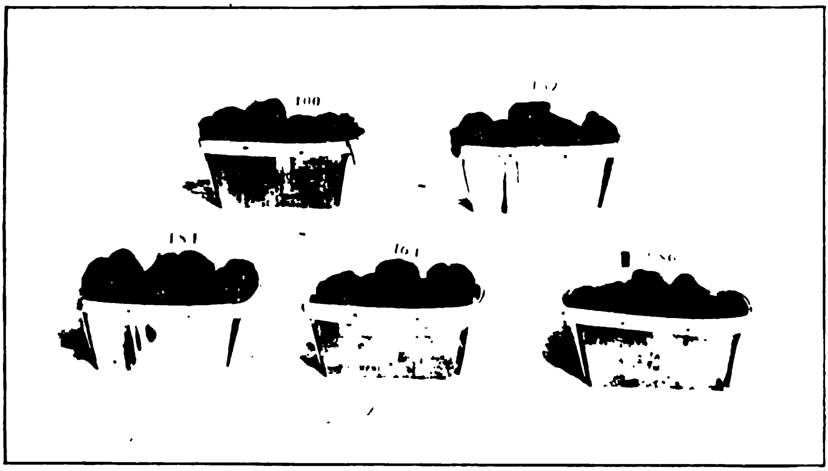

Fig. 3.—Strawberry seedlings.

No. 100. McKinley X Ridgeway.
Nos. 157 and 164. Crescent X Glen Mary.
No. 181. McKinley X Ridgeway.
No. 186. Glen Mary X McKinley.

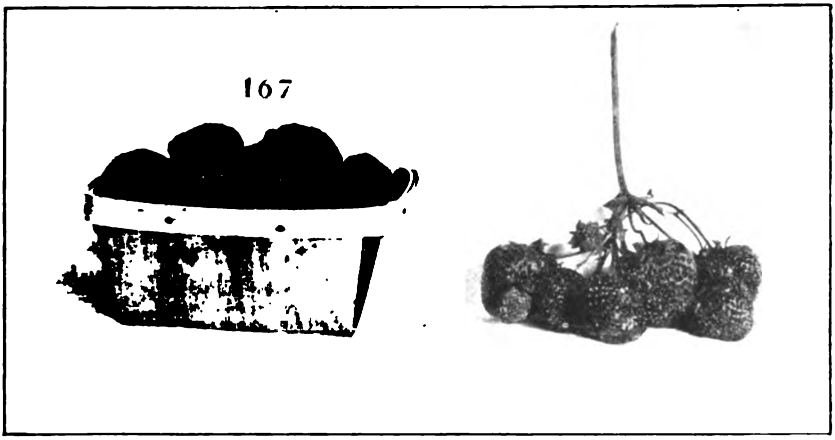

Fig. 4.—No. 167, Glen Mary X Wm. Belt.

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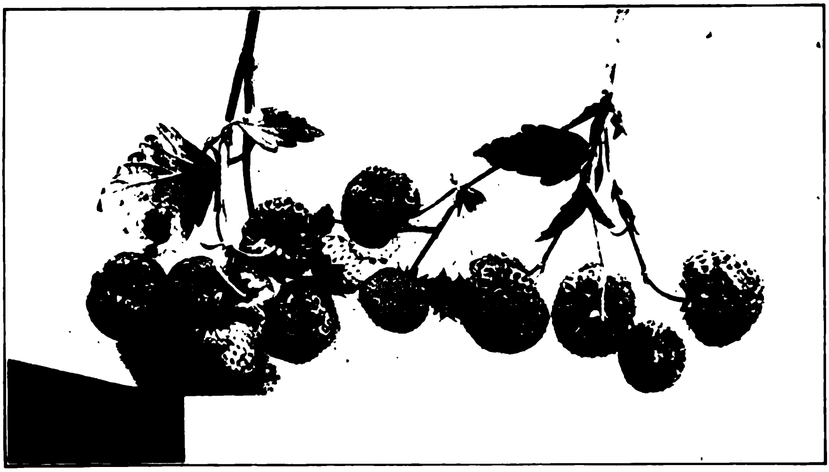

Fig. 5.—A seedling of Hunn X Ideal. Photographed July 13, 1904, showing lateness of its season.

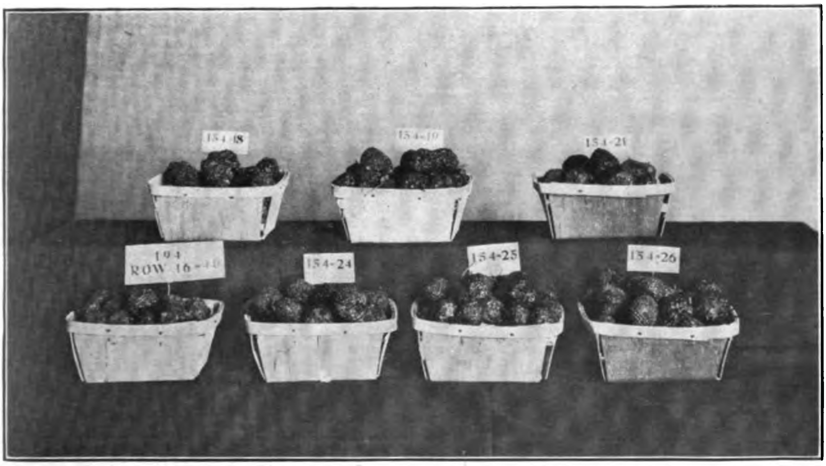

Fig. 6.—Seedlings containing one-fourth parentage of the wild strawberry.

Flavor

a=acid; sub=subacid; fl=flat; s=sweet; sp=sprightly; msk=musky.

**Color*

l=light; d=dark; o. s.=opera scarlet; n. s.=new scarlet; s=scarlet; car=cardinal; cr=crimson.

Calyx

d=depressed; c=close; r=raised; l=large; m=medium; s=small.

Core

s=solid; sp=spongy; h=hollow.

Seeds

Position

r=raised; d=depressed; d. d.=deeply depressed; p=prominent.

Color

l=light; c=colored; m=mixed.

Among the seedlings in fruit a number were selected for future observation, ten plants being taken from each. Two from which ten plants had been previously taken seemed sufficiently promising to warrant planting in larger numbers. One of these was a seedling of McKinley X Ridgeway, being known as No. 100 in our field notes. A copy of the score of this variety made in the field is here given:

STRAWBERRY

Variety, No. 100. McKinley X Ridgeway

SCALE - POINTS 10 - Perfect

Plant

Vigor 10	Disease Resistance 9	Frost Resistance

Fruit

Productiveness 8	Size 9	Regularity 8
Appearance 8	Texture 9	Quality 7.5
Fragrance 5	Rot Resistance 9	

DESCRIPTION

Plant

Leaves Large, tall, wrinkled	
Runners Good	Fruiting Stems Tall, fairly strong
Bloom Season Medium	Sex Perfect

---

* Based on Brainard & Armstrong's colored silks.

Fruit

Form Short, flattened	Flavor *Sub*-acid	
Color Light	Color of Flesh White, tinged	
Calyx Large, depressed	Core Solid, *good*	
Seeds Position Depressed	Size Medium to large	Color Light
Season First	Heaviest	Last

General Notes A fine berry, healthy and very promising.

Date................ Observer

This proved to be medium in season, the heaviest picking having been obtained July 1st. The yield was 169½ ounces from a strip of row produced by the ten plants originally set. This yield was surpassed by only one variety planted at the same time under similar conditions. The color of this berry was bright and attractive. No. 101, which was the one surpassing it in yield, was very dark and seedy in appearance. The rating for productiveness given on the score was made from appearances only, as observed in the field, not from the actual yields obtained. A basket of the fruit, in connection with that of other seedlings, is shown at Figure 3.

Another seedling which proved particularly promising in 1904 was No. 167, a seedling of Glen Mary X Wm. Belt, the score for which is also shown. This berry ranked well in yield, though surpassed by several others. In season it proved to be medium, the heaviest pickings being made June 25th and July 1st. This variety is particularly commended by its appearance. The fruit is shown at Figure 4.

STRAWBERRY

Variety, No. 167. Glen Mary X Wm. Belt.

SCALE - POINTS 10 - Perfect

Plant

Vigor 8	Disease Resistance 9	Frost Resistance

Fruit

Productiveness 7.5	Size 9	Regularity 9
Appearance 9	Texture 7	Quality 8.5
Fragrance 8	Rot Resistance 6	

DESCRIPTION

Plant

Leaves Large, dark
Runners Fruiting Stems Numerous
Bloom Season Late Sex Perfect

Fruit

Form Short, conical Flavor Sub-acid
Color Light Color of Flesh Like outer color
Calyx Medium, close Core Open, hard center.
Seeds Postion Prominent Size Medium Color Light
Season First Heaviest Last
General Notes A very fine appearing berry of good fair quality. Still some good berries July 6
Date................. Observer

One point aimed at in the production of seedlings has been to secure late ripening, coupled with other good qualities. Considerable progress has been made in this direction. Nearly all the seedlings of Hunn X Ideal ripen late. Figure 5 shows one of these, photographed July 13, 1904. This was the date of our last picking and shows the lateness of this berry, since these clusters were practically at their best on that date. A number of others surpassed any of the so-called late varieties which we have had growing on the grounds in company with them.

Among the first crosses made were several in which Wm. Belt was fertilized with pollen of the wild strawberry. The seedlings obtained from this first cross bore fruit too small to be of value, possessing in a marked degree the characteristics of the wild berry. They were inveterate plant-makers, soon filling the row completely with runners. The fruit, while small, was usually of good quality, resembling the wild berry in flavor and appearance. A few of the most promising were chosen and used for again crossing with garden varieties. A number of these seedlings were in fruit in 1904 and some of them were very promising, showing good size of fruit and desirable characteristics of plant. Some of these also retained the flavor of the wild berry to a perceptible extent. Fruit from a number of them is shown in Figure 6. These are being retained for future observation.

DIVISIONS OF AGRONOMY AND CHEMISTRY.

MISCELLANEOUS ANALYSES

(Other than those which will be published in connection with special articles).

B. L. HARTWELL, J. W. KELLOGG, AND M. STEEL.

"HYDRATED" LIME.

From the Rockland Lime Co., Rockland, Me.

	Per cent.
Calcium oxid (lime)	70.90
Magnesium oxid (magnesia)	0.61

The lime was slaked by steam, and then bolted to secure it in a fine condition.

MUCK (Air-dried).

From M. A. Evans, Arnolds Mills.

	Per cent.
Water	6.27
Nitrogen	1.04
Residue after ignition	39.90

SOOT (From Soft Coal).

From Carl Jürgens, Newport.

I. Taken from chimney.
II. Taken from boiler tubes.

	Per cent.	
	I.	II.
Nitrogen	0.91	0.17

STREET SWEEPINGS.

From Carl Jürgens, Newport.

	Per cent.
Nitrogen	0.25

The amounts of phosphoric acid and potash present were too small to have any practical value.

ASHES.

From The Rhode Island Hospital, Providence.

	Per cent.
Phosphoric acid	0.92
Potassium oxid (potash)	2.18
Calcium oxid (lime)	9.00
Insoluble matter	53.27

The above ash was the residue from burning the refuse and sweepings of the hospital, including splints, bandages, animal matter, etc.

WOOD ASHES.*

From The Woonsocket Spool and Bobbin Works.

	Per cent.
Phosphoric acid	2.28
Potassium oxid (potash)	11.64

The ashes resulted from the use as fuel of the refuse from spools and bobbins.

WOOD ASHES.*

From F. E. Fogg, Tiverton.

	Per cent.
Phosphoric acid	2.53
Potassium oxid (potash)	14.18

ASHES.

From E. D. Smith & Co., Providence.

	Per cent.
Phosphoric acid	0.29
Potassium oxid (potash)	Trace.
Calcium oxid (lime)	7.49
Ferric and aluminic oxids	73.29

These ashes were produced from coal, and from sawdust which had been used for removing the iron turnings from screws.

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* The amount of lime must have been approximately 30 per cent., but it was not actually determined. The ashes from Tiverton were from oak wood.

BLACK BONE.

From C. N. Potter, Elmwood Station, Providence.

	Per cent.
Nitrogen	0.69

This material is used in the case-hardening of steel. The phosphoric acid was not determined, but the usual content is about 29 per cent.

GUANO.

From Edmund Mortimer & Co., New York.

	Per cent.		
	A.	B.	C.
Nitrogen	9.27	2.77	3.22
Phosphoric acid	10.58	22.42	20.53
Potassium oxid (potash)	2.29	3.57	4.07

ACID PHOSPHATE (DISSOLVED PHOSPHATE ROCK).

	Per cent.	
	A.	B.
Phosphoric acid	16.96	15.35

This material contains from 13 to 15 per cent of "available" phosphoric acid.

FLOATS (UNDISSOLVED PHOSPHATE ROCK).

	Per cent.
Phosphoric acid	30.27

I. FINELY GROUND BONE.
II. DISSOLVED BONE.

	Per cent.	
	I.	II.
Nitrogen	2.90	1.56
Phosphoric acid	25.03	15.37

I. STAR FISH (air-dried).
II. DRIED BLOOD.

	Per cent.	
	I.	II.
Nitrogen	4.81	10.47

I. NITRATE OF SODA.
II. SULFATE OF AMMONIA.

	Per cent. I.	*Per cent.* II.
Nitrogen	15.63	21.28

MURIATE OF POTASH.

	Per cent. I.	*Per cent.* II.
Potassium oxid (potash)	47.43	52.60

I. HIGH GRADE MURIATE OF POTASH.
II. HIGH GRADE SULFATE OF POTASH.

	Per cent. I.	*Per cent.* II.
Potassium oxid (potash)	59.58	49.86

POTASSIUM CARBONATE.

	Per cent. I.	*Per cent.* II.
Potassium oxid (potash)	66.00	67.63

I. SODIUM CHLORID (Common Salt).
II. SODIUM CARBONATE.

	Per cent. I.	*Per cent.* II.
Sodium oxid (soda)	52.76	57.02

RHODE ISLAND CORN BRAN.

From Boyd Bros' Wind Grist-Mill, Portsmouth.

	Per cent.
Crude fat	3.71
Protein	7.13

COTTON-SEED MEAL.

	Per cent.
Protein	26.38

This sample contained a large amount of cotton-seed hulls. A good cotton-seed meal should contain not less than 41 per cent. of protein.

THE EFFECT OF POSTPONING THE AMMONIUM-CITRATE TREATMENT OF THE WATER-INSOLUBLE PORTION OF FERTILIZERS.[1]

B. L. HARTWELL AND J. W. KELLOGG.

It has been the custom of the Rhode Island Station to make the determinations of soluble phosphoric acid in fertilizers, and to treat the residues from the same with ammonium citrate, in all of the samples soon after they are collected. The air-dried residues from the ammonium-citrate treatment are placed in small, turned, wooden boxes, and the determinations of the phosphoric acid in these residues (insoluble phosphoric acid) are made later at any convenient time.

This course has been pursued in order to avoid the changes in the amounts of the soluble, reverted, and insoluble phosphoric acid which usually take place upon standing. Such a plan becomes necessary, when several months elapse before the fertilizer analyses are completed, in order that the amounts of the different forms of phosphoric acid found by analysis shall correspond with those actually present at the time the fertilizers were used.

The principal objection to this method of procedure is, that work involving all of the samples delays the completion of the analysis of any smaller number of the fertilizers whose publication it may be desired to hasten.

It seemed probable that if the soluble phosphoric acid were removed promptly, and the residues thoroughly air-dried, that it would not be necessary, in order to guard against changes in the amount of insoluble phosphoric acid, to extract the reverted acid until later, whenever it was convenient. The present work was undertaken to secure some indications upon this point.

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[1] Presented before the Association of Official Agricultural Chemists of the United States, at the St. Louis meeting, in 1904.

Two portions of two grams each, taken from the individual samples, were both extracted with water in the usual manner, to remove the soluble phosphoric acid, and the residues were dried in the air. Only one of the residues in each case was treated promptly, within a day or two, with the ammonium-citrate solution, to remove the reverted phosphoric acid. The residues from this treatment, as well as those from the portions which had been extracted with water only, were placed in the wooden boxes. After about fifteen weeks the residues from the extraction with water only were digested with the ammonium-citrate solution, and the insoluble phosphoric acid determined at once. At the same time the phosphoric acid was determined in the residues from the earlier treatment with ammonium citrate.

The determinations from each solution were repeated upon subsequent days, and the results (b) are placed beside the first determinations (a) from the same solutions.

The weights of magnesium pyrophosphate in grams, representing the insoluble phosphoric acid per one-half gram of fertilizer, are given below:

	Series I. Early extraction of the "reverted."		Series II. The "reverted" extracted about 15 weeks later.		Difference between I and II.
	a.	b.	a.	b.	
1........	.0080	.0084	.0080	.0073	—.0005
2........	.0187	.0185	.0179	.0180	—.0004
3........	.0113	.0114	.0121	.0122	+.0008
4........	.0142	.0142	.0149	.0148	+.0007
5........	.0178	.0177	.0195	.0177	+.0008
6........	.0244	.0245	.0223	.0223	—.0022
7........	.0181	.0182	.0184	.0177	—.0001
8........	.0075	.0077	.0081	.0078	—.0004
9........	.0125	.0124	.0124	.0119	—.0003

	Series I. Early extraction of the "reverted."		Series II. The "reverted" extracted about 15 weeks later.		Difference between I and II.
	a.	b.	a.	b.	
10........	.0122	.0125	.0135	.0134	+.0011
11........	.0163	.0163	.0167	.0160	+.0001
12........	.0135	.0142	.0147	.0146	+.0008
13........	.0237	.0236	.0233	.0228	—.0004
14........	.0156	.0156	.0162	.0164	+.0007
15........	.0160	.0160	.0138	.0134	—.0024
16........	.0137	.0139	.0143	.0138	+.0003
17........	.0264	.0258	.0209	.0207	—.0053

Before drawing any conclusions from the above differences it is necessary to know how wide a variation is liable to occur in routine work between two determinations of insoluble phosphoric acid in a given sample under our conditions, where the extractions of the soluble and the reverted phosphoric acid are made upon different days from separate portions of the sample, and where a single result only is secured from each residue containing the insoluble phosphoric acid. From an inspection of a large number of results it was found that the difference was rarely *greater* than 1.5 milligrams (0.19%), it being in most cases much less. It may be seen from the above results that in the cases of Nos. 6, 15, and 17 only was this limit exceeded; so that the differences in the remaining instances must be considered as falling within the limit of error liable to occur under the conditions of the work. Whether the reduction in amount of insoluble phosphoric acid in Nos. 6, 15, and 17 was actually caused by the postponement of the ammonium-citrate extraction, as is indicated by the results, could only be ascertained with certainty by a larger number of determinations.

If it should be proven that there is in certain isolated cases somewhat less insoluble phosphoric acid when the extraction with ammonium citrate is postponed for several months, no injustice would be done to the manufacturer, as the available phosphoric acid would become correspondingly greater.

It is interesting to note that with the other numbers taken together there is a tendency towards an increased amount of insoluble phosphoric acid in the residue from the later extraction with ammonium citrate, although the difference in every case is within the limit of error. It is not improbable that any difference which might occur would be plus or minus, depending upon the nature of the fertilizer.

It is realized that the results herein recorded do not settle the question at hand; but they indicate that no large error will arise if, for the sake of greater convenience, the dried residues from the extraction with water are kept a number of weeks before the "reverted" phosphoric acid is removed by the ammonium citrate.

PHOSPHORIC ACID DETERMINATIONS BY THE METHOD OF IGNITION WITH MAGNESIUM NITRATE AND BY THAT OF DIGESTION WITH ACIDS.[1]

BY B. L. HARTWELL, A. W. BOSWORTH, AND J. W. KELLOGG.

The method described by A. Neumann[2] provides for the destruction of the organic matter by digesting the material in a Kjeldahl flask with a mixture of equal volumes of concentrated sulfuric and nitric acids, adding small amounts of the acid mixture from time to time, until the destruction of the organic matter is completed. Fifty grams of ammonium nitrate are then added to the cooled, diluted solution, the temperature is increased to 70° or 80°C., and the molybdic mixture added. After 15 to 20 minutes standing, the solution is filtered and the phosphoric acid determined volumetrically in the precipitate.

The method seemed to offer some advantages over the older methods, and it was decided to give it a trial in determining phosphoric acid in the oat plant and in turnips, using the method exactly as outlined except that the ammonium phosphomolybdate was dissolved in ammonium hydroxid, and the phosphoric acid determined gravimetrically in magnesium pyrophosphate, instead of using the volumetric method. A sample of oats, which yielded

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[1] This paper was published in the Journal of the American Chemical Society, March, 1905.

[2] Arch. Anat. u. Physiol., Physiol, Abt. 159 (1900); Ztschr. Physiol. Chem. 37,115 (1902–1903); Ibid 43,32 (1904). See also E. Poher, Ann. Sci. Agron. 2d. ser. 8., T. 2, 441 (1902–3).

0.0377 gram of magnesium pyrophosphate by the magnesium nitrate method of the Association of Official Agricultural Chemists, yielded by the Neumann method, with 15 to 20 minutes digestion, only 0.0309 gram. In the case of turnip roots, 0.0331 gram of magnesium pyrophosphate was obtained by the magnesium-nitrate method and 0.0326 gram by the Neumann method. Upon further digestion of the filtrate from the yellow precipitate (ammonium phosphomolybdate) secured by the Neumann method more precipitate was obtained, indicating the advisability of a longer digestion. Other determinations were next made in the same material by digesting for one hour at 65°. The oats yielded 0.0321 gram and the turnip roots 0.0319 gram as against 0.0377 and 0.0331 gram respectively by the magnesium-nitrate method. There seemed to be some difficulty in obtaining all of the phosphoric acid by precipitating with molybdic mixture according to the conditions as outlined in the method, and even upon continuing the digestion for one hour at 65°. The details of the modified method, as used in securing the results recorded on succeeding pages, and referred to herein as the acid method, are as follows: 5 grams of the substance were digested in a Kjeldahl flask. A low heat and small amount of the acid mixture were used at the beginning, the heat being gradually raised and subsequent small portions of the acid mixture added, in the manner described by Neumann, until the least amount of acid had been used which was necessary for the destruction of the organic matter, perhaps 40cc. in all. After diluting and cooling the solution was made ammoniacal, acidified with nitric acid, and treated with the molybdic mixture[1] of the A. O. A. C., to which 15 grams of ammonium nitrate per 50cc. of solution had been added. Some difficulty was experienced at first in securing a complete precipitation of the ammonium phosphomolybdate, due perhaps to the large amount of ammonium sulfate present. A large volume of solution, considerable excess of molybdic mixture, an extra amount of ammonium nitrate, and digestion at 65° for a few hours were the conditions finally adopted.

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[1] U. S. Dept. of Agr., Bur. of Chem., Bul. 46, p. 11, (1898).

In order to compare the results obtained by the above method with those by a well-known and thoroughly familiar method, the following was selected. To 5 grams of substance in a porcelain dish were added 10cc. of the official magnesium-nitrate solution[1] and sufficient water to allow the entire mass to be moistened. The contents of the dish were dried and ignited. The residue was treated with hydrochloric acid and, after evaporating and drying at about 120° to avoid any possibility of the results being increased by soluble silica, the mass was digested with hydrochloric acid. The filtered solution was neutralized with ammonium hydroxid, about 30 grams of ammonium nitrate, 40cc. of half strength nitrate acid and 50cc. of molybdic solution added, and the digestion conducted at 65° for an hour or more. The two methods were alike after this point, the phosphoric acid being determined in magnesium pyrophosphate as usual. The addition of the nitric acid was found necessary, under our conditions, to prevent the separation of molybdenum compounds other than ammonium phosphomolybdate, which otherwise were thrown down and interferred with clear filtration and washing. The evaporation to remove silica was perhaps an unnecessary precaution, as is indicated by the following results upon a number of different samples of oat plants. The results marked *a* were secured when evaporation and drying to render all silica insoluble were resorted to, and those marked *b* were from separate portions of the same samples when these precautions to render the silica insoluble were not taken:

GRAMS OF MAGNESIUM PYROPHOSPHATE OBTAINED FROM 5 GRAMS OF OATS.

a....	0.0398	0.0453	0.0425	0.0398	0.0377	0.0333	0.0435	0.0373	0.0390
b....	0.0394	0.0456	0.0430	0.0414	0.0377	0.0328	0.0434	0.0370	0.0390

The following results represent the grams of magnesium pyrophosphate, obtained by the acid and magnesium-nitrate methods previously described, from separate five-gram portions of different samples. It may be seen that from one to three independent determinations were made in a given sample by the two methods, results upon each sample being arranged vertically:

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[1] loc. cit. p. 12.

FLAT TURNIP ROOTS.

No. of sample.	51	53	55	57	58	59
Acid method	0.0496	0.0644	0.0561	0.0630	0.0576	0.0553
	0.0516	0.0644	0.0535	0.0684	0.0620	0.0556
	0.0532	......	......	0.0656	0.0621	......
Magnesium-nitrate method	0.0493	0.0613	0.0534	0.0630	0.0560	0.0539
	0.0502	0.0613	0.0520	0.0640	0.0592	0.0555
	......	0.0611	0.0534	......	0.0584	0.0541

No. of sample.	60	61	63	65	67	69
Acid method	0.0533	0.0392	0.0340	0.0320	0.0321	0.0486
	0.0532	......	0.0344	......	......	0.0493
Magnesium-nitrate method	0.0511	0.0389	0.0323	0.0320	0.0320	0.0476
	0.0530	......	0.0339	......	......	0.0475

OAT PLANT (Aerial portion).

No. of sample.	51	53	55	57	59
Acid method	0.0424	0.0477	0.0404	0.0419	0.0425
Magnesium-nitrate method	0.0398	0.0456	0.0404	0.0430	0.0414
	0.0394	0.0453	0.0376	0.0425	0.0398
	......	......	......	......	0.0390

No. of sample.	61	63	65	67	69
Acid method	0.0379	0.0354	0.0450	0.0368	0.0388
Magnesium-nitrate method	0.0377	0.0328	0.0300	0.0370	0.0390
	0.0377	0.0333	0.0435	0.0373	0.0390

The average amount of magnesium pyrophosphate obtained per five grams of material in the case of the turnip roots was 0.0493 gram by the acid method and 0.0480 gram by the magnesium-nitrate method, which are respectively equivalent to 0.629 and 0.612 per cent. of phosphorus pentoxid. Similarly, with the oat plant, 0.0409 gram of magnesium pyrophosphate was obtained by the acid method and 0.0397 gram by the magnesium-nitrate method, which are respectively equivalent to 0.522 and 0.506 per cent. of phosphorus pentoxid.

The results by the acid method are on an average about three per cent. higher than those by the magnesium-nitrate method. It is not believed, however, that the magnesium-nitrate method failed to secure all of the phosphoric acid present in the crop, but rather that there were impurities present in the magnesium pyrophosphate obtained by the acid method; it was frequently of an abnormal color and had a reddish tint, in which case a quite strong reaction for iron was obtained. Furthermore, in a number of instances the magnesium pyrophosphate obtained by each method was dissolved in nitric acid, and upon reprecipitation and ignition the results by the two methods were more nearly alike.

By a comparison of the results with turnip roots, in which case more than one determination was frequently made by *each* of the methods, it may be seen that there was more difficulty in obtaining parallel results with the acid method than with the other.

It should be said, in explanation of the frequent wide differences in the determinations by a given method, that it was thought advisable to include *all* of the results, thereby affording an indication of the capabilities of the two methods as followed in the routine analysis of a considerable number of samples, where the time element would preclude reprecipitation for the purpose of increasing the purity of the final product.

It is recognized that a wider experience with the acid method would probably lead to desirable modifications, but for the interest of those who might wish to use the method the results are presented at this time.

NOTES ON THE USE OF ACETIC AND OF OXALIC ACID FOR EXTRACTING THE CHARRED MATERIAL IN PREPARING ASH.[1]

B. L. HARTWELL AND J. W. KELLOGG.

When material is incinerated with a view of retaining in the ash all of the potassium and sodium, it is usually advisable to extract the substance, obtained by charring at a low heat, with some solvent which shall remove the soluble ash constituents before the charred material is subjected to the higher heat necessary for complete incineration. The method[2] of the Association of Official Agricultural Chemists suggests water or acetic acid for this purpose, depending upon circumstances.

In the analysis of the ash of mixed grasses, principally timothy and redtop, it was found that about 20 per cent., after dehydrating the silica, consisted of material insoluble in hydrochloric acid. Very little "sand" could have been present, for the samples were cut from a compact turf and the only source of dirt was such dust as may have adhered to the growing plants. Practically no effervescence occurred upon adding hydrochloric acid to this ash, there being sufficient acid radicals other than carbon dioxid to combine with the bases.

It had been the general custom at this Station in the preparation of plant ash to char the substance at a low temperature and to extract the charred material thoroughly with hot water, in order to remove alkalies and to aid in the incineration. A single test with the hay showed that eight per cent. of the total amount of potassium and sodium was left unextracted by the hot water, even though the charred material was digested with the same for some time. It seemed, therefore, that it might be desirable in some cases to use an acid in the extraction to guard against the possibility of any volatilization of the alkalies during the final ignition; and dilute acetic acid was given a trial in comparsion with the water. It was noticed invariably that the portion of the ash from the charred, extracted material was the browner where the acetic acid was used, indicating that the proportion of iron was greater, due probably to the more thorough extraction of the calcium by the acetic acid; and also that it dissolved with greater difficulty in hydrochloric acid. In a few instances the ash from the extract and that from the charred, extracted material were kept separate, and the total silica determined in each case. The amount of silica was noticeably greater in the extract secured by water digestion than when acetic acid was used.

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[1] To be read at the Annual Convention of the Association of Official Agricultural Chemists, to be held in Washington, D. C., in November, 1905.

[2] U. S. Dept. of Agr., Bur. of Chem., Bul. 46, p. 77 (1898).

Chicory tops, carefully brushed to remove all soil which had spattered upon them during heavy showers, yielded an ash which generally contained, after dehydrating the silica, about six per cent. of material insoluble in hydrochloric acid. In the case of this material there was considerable carbon dioxid in the ash; but it will be noticed that the proportion of insoluble matter was much less than in the ash from hay, in spite of the fact that there was greater liability of contamination by soil in the case of the chicory tops, which were from a hoed crop. In making a comparison of water and of acetic acid for extracting the charred material of the chicory tops, a liberal quantity of the latter, after charring, was mixed and divided into two equal portions, one of which was thoroughy extracted with dilute acetic acid and the other with water. The comparsion was, therefore, more exact than in the case of the hay where the extraction was from two separately charred portions, which may have varied slightly as regards the extent of charring. Eighty-four per cent. of the crude ash was obtained from the acetic acid extract, whereas only fifty per cent. was in the aqueous extract. Twenty-two per cent. of the total silica was found in the acetic acid extract and three per cent. in the aqueous extract. In this instance a larger proportion of the silica was extracted by the acid than by the water, while with the hay the reverse seemed to be true, due, perhaps, to the precipitation of some of the soluble silica of the highly siliceous hay, and to its retention with the charred material. The ash from the charred chicory tops, exclusive of that from the extract, was browner and dissolved with greater difficulty when acetic acid was used as the extracting solution than when water was employed, as was also true in the case of the hay. It seems likely that the more complete removal of the lime by the acetic acid is a detriment to the final incineration of the charred material from certain plant substances, resulting, as was noticed, in an ash which is more difficult to dissolve in hydrochloric acid.

The total amount of crude ash was invariably greater when acetic acid rather than water was used. This was due in part, at least, to carbon from the incomplete ignition of the acetates in the extracted material; for upon the evaporation of the extract, after combining it with the ash from the charred material, and subsequently igniting, a more or less blackened mass was obtained, which could not be burned to a light-colored ash without increasing the temperature to a degree which might result in volatilization of alkalies.

It seemed as though the difficulties in using acetic acid could be overcome by substituting oxalic acid. The latter, of course, would leave the calcium with the charred material, and, owing to the larger proportion of oxygen to carbon in this acid than in acetic acid, no carbonaceous residue would be left upon ignition. Therefore a comparasion was made between dilute oxalic acid and water for extracting the charred material from hay of similar character to that mentioned previously. Equal portions of the charred material were extracted by the two solutions, and the silica in the crude ash from the extract and also from the charred material itself determined separately. From four different samples of hay, 90, 95, 87, and 89 per cent. respectively of the total silica was found in the charred mass which had been extracted with oxalic acid, while that left from the extraction of like material with water usually constituted less than 70 per cent. of the total silica.

It was thought that the difference in the relative amounts of the various ash ingredients in the charred substance, depending upon whether water or acid had been used in the extractions, might have an influence upon the amount of impurity which is almost invariably contained in the total silica. The insoluble matter in the ash of the charred substance from hay, referred to in the preceding paragraph, was treated, therefore, with hydrofluoric acid to volatilize the silica, and the residue soluble in hydrochloric acid was determined. The grams of residue per thirty grams of four different samples of hay are given below:

	I.	II.	III.	IV.
When the "char" was extracted with water....	.0342	.0203	.0159	.0170
When the "char" was extracted with oxalic acid	.0166	.0150	.0105	.0168

The above residues represent the following percentages of the insoluble matter from which they were obtained,

	I.	II.	III.	IV.
When the "char" was extracted with water..........	13.3	12.0	9.7	10.0
When the "char" was extracted with oxalic acid.....	6.3	6.8	4.6	7.5

These results indicate that the insoluble matter in the ash from hay may contain less non-siliceous material if oxalic acid instead of water is used for extracting the charred substance. The insoluble matter in the ash from carrots and radishes, however, which was about one-fourth as much as from the hay, yielded no greater residue from treatment with hydrofluoric acid when water was used to extract the charred material than when oxalic acid was used.

When the samples to be analyzed are free from adhering soil, it is advisable to treat the insoluble matter of the ash with hydrofluoric acid in order to volatilize the silica, which is then represented by the difference in weight caused by the action of the hydrofluoric acid. The residue may then be dissolved in hydrochloric acid and combined with the main portion of the solution before diluting to a definite volume. This residue is frequently of considerable magnitude, depending upon the nature of the material and the method of ignition, and often causes unsatisfactory parallels and considerable error when included in the total silica, as well as a minus error in the determinations of the non-siliceous ingredients. If any considerable amount of soil is present with the sample, it would be unwise, of course, to use hydrofluoric acid as suggested above, for the reason that the ingredients of the soil would then be included with the ash constituents and lead to plus errors.

Unless the preliminary ignition is quite thorough before the charred material is extracted, to remove the alkalies previous to complete incineration, the aqueous extract will often be dark colored from organic matter. This is not apt to be the case, however, when oxalic acid is used for extraction.

A complication will arise in the use of oxalic acid, in connection with the determination of calcium oxid, unless the oxalates are completely decomposed, for the reason that calcium oxalate will be precipitated with the iron phosphate. Some uncertainty may be felt as to whether the heat required to decompose all of the oxalates, which may be present with a large amount of ash, could lead to any volatilization of alkalies. It seems improbable, considering the combinations in which the alkalies occur at this stage, that they would be volatilized; but the only data obtained bearing upon this point are comparisons of results secured by using water for extracting the charred material from one portion of a sample, and oxalic acid for extracting the charred material from another portion of the same sample. A single determination only was made in each case, and the results per 1.25 grams of air-dry material are given below:

		POTASSIUM AND SODIUM CHLORIDS. (gram.)		POTASSIUM CHLOPLATINATE. (gram.)	
		Water.	Oxalic acid.	Water.	Oxalic acid.
Carrot roots....................	I.	.0937	.0929	.0809	.0803
	II.	.1170	.1201	.0718	.0724
	III.	.0821	.0819	.0876	.0864
	IV.	.0744	.0723	.0938	.0925
Carrot tops.....................	I.	.1214	.1192	.0597	.0576
	II.	.0746	.0748	.0904	.0904
Radish roots....................	I.	.1935	.1918	.3696	.3680
	II.	.1696	.1673	.3294	.3246

The above differences are considered within the limit of analytical error for routine work carried on in the manner described, and do not indicate any differences due to the method of extraction. It should be said in this connection that the residues from treating the insoluble matter of the ash with hydrofluoric acid were dissolved in hydrochloric acid and included with the other acid-soluble ingredients of the ash, so that any possible differences, which might have occurred from that source, would not appear in the above figures.

The amount of crude ash was generally greater when oxalic acid instead of water was used for extracting. As would be expected, there were no evidences of carbon left from the decomposition of the oxalates, and it seems probable that the amount of ash was greater because it was more thoroughly carbonated. With hay, where the evolution of carbon dioxid upon the addition of hydrochloric acid is small, the greater effervescence from the ash prepared by extraction with oxalic acid could be readily noticed.

ON THE EFFECT OF LIMING UPON CERTAIN CONSTITUENTS OF A SOIL.

B. L. HARTWELL AND J. W. KELLOGG.*

In connection with experiments conducted at this Station regarding the effect of lime upon the growth of plants, some chemical work has been done which shows certain effects of this material upon the soil itself. In 1893 the permanent plats Nos. 23, 25, 27, and 29 were set apart for determining the relative efficiency of nitrogen in nitrate of soda and in sulfate of ammonia. Since that time all of the plats have received equal annual applications of dissolved bone-black, muriate of potash, and nitrogen, and occasional additions of magnesium sulfate. Sulfate of ammonia has been used as the source of nitrogen for plats 23 and 25, and nitrate of soda for plats 27 and 29. Plats 25 and 29 have received the following applications of air-slaked lime per acre, namely: in 1893, 5,400 pounds; in 1894, 1,000 pounds; and in 1902, 1,046.1 pounds; making in all over 3.7 tons. One of the plats receiving sulfate of ammonia, No. 23, and one of those to which nitrate or soda has been added, No. 27, have never received any air-slaked lime. Miscellaneous crops have been grown across these plats, and the cultivation has been the same for all. In December of 1896 samples of the surface soil were taken from the four plats by making borings along a line extending across them. The percentages of humus† in the oven-dry soil, finer than 1-50 inch, were as follows:

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* Many suggestions in connection with this work were received from Dr. H. J. Wheeler.

† The term "humus" as used in this article refers to the organic matter extracted by dilute ammonium hydroxid after a preliminary extraction with dilute hydrochloric acid. See Wiley's Agricultural Analysis, Vol. 1, p. 326 (1904), for method employed.

Sulfate of ammonia plat, unlimed	4.00
Sulfate of ammonia plat, limed	3.60
Nitrate of soda plat, unlimed	4.29
Nitrate of soda plat, limed	3.49

Samples of soil were again taken from the four plats in the spring of 1904; at this time the borings were made so that the entire plat might be represented by each sample. The percentages of humus in the oven-dry soil, finer than 1-25 inch, were as follows:

Sulfate of ammonia plat, unlimed	3.76
Sulfate of ammonia plat, limed	3.25
Nitrate of soda plat, unlimed	3.78
Nitrate of soda plat, limed	3.33

These results should not be compared with those from the year 1896, because the samples were both taken and prepared differently. Attention is directed at this time merely to the fact that the amount of humus in the limed soil is from 10 to 19 per cent. less than in the corresponding unlimed soil, when both sets of results are taken into consideration.

The following results taken from an earlier publication* of this Station show the variations in the content of humus in a soil after growing maize, oats, and rye, each for one year, in large pots which were sunk in the ground. The soil was taken from a portion of the same field in which the previously mentioned plats are located, and the limed pots received, at the beginning of the experiment, air-slaked lime at the rate of four tons per acre.

Humus in oven-dry soil.

	Per Cent.
Sulfate of ammonia pots, unlimed	3.93
Sulfate of ammonia pots, limed	3.63
Nitrate of soda pots, unlimed	3.93
Nitrate of soda pots, limed	3.42

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* Annual Report, (1899) p. 155.

The following loss in weight resulted upon ignition of the soil collected in 1904 from plats 23, 25, 27, and 29, which had been oven-dried at 150°C before ignition:

	Per Cent.
Sulfate of ammonia plat, unlimed	7.12
Sulfate of ammonia plat, limed	6.88
Nitrate of soda plat, unlimed	7.24
Nitrate of soda plat, limed	6.67

The above loss by ignition can not, of course, be attributed entirely to organic matter; but it is fair, perhaps, to assume that the changes in weight due to other causes would be about equal on all of the plats, and that the smaller losses from the limed soil indicate that the total organic matter has been somewhat decreased.

In view of the smaller quantities of humus and of organic matter in the limed than in the unlimed soil, it is of interest to record the following amounts of nitrogen, calculated to oven-dry soil, in the samples collected in 1904:

	Per Cent.
Sulfate of ammonia plat, unlimed	0.223
Sulfate of ammonia plat, limed	.222
Nitrate of soda plat, unlimed	.225
Nitrate of soda plat, limed	.205

The differences in the first three results are within the limit of analytical error (about .005 per cent.); the limed plat receiving nitrate of soda being the only one which shows a decreased amount of nitrogen in the soil. It should be recalled that liberal applications of nitrogen were made annually to each plat.

The amount of humus in the limed plats is not only less, as has been recorded above, but the composition of the compounds containing humus and ash constituents is different. This is shown by extracting the soil directly with dilute ammonium hydroxid, without the preliminary treatment with hydrochloric acid as required in the determination of humus. The precipitate, formed by acidifying this ammoniacal extract with hydrochloric acid, is dried and the further loss upon ignition is designated herein as "free" humus.*

Free Humus in Oven-dry Soil. (*Sampled in* 1904.)

	Per Cent.
Sulfate of ammonia plat, unlimed	1.47
Sulfate of ammonia plat, limed	.99
Nitrate of soda plat, unlimed	1.61
Nitrate of soda plat, limed	.96

The free humus equals 39 and 43 per cent., respectively, of the humus in the case of the unlimed plats, while with the limed ones it equals only 30 and 29 per cent., respectively, of the humus. The free humus in the samples collected in 1896 showed practically the same relation to the humus as the above.

The effect exerted by lime upon the organic matter of a given soil depends to a considerable extent upon the degree of acidity or alkalinity of the soil. It is important, therefore, to note some of the characteristics of the particular soil from which the results herein recorded have been secured. The soil contains no calcium carbonate, and turns blue litmus paper decidedly red. Many of the common agricultural plants fail to make a satisfactory growth until some alkaline material has been applied to the soil. The conditions are made worse by the addition of manurial substances which have the effect of increasing the acidity; for example, sulfate of ammonia. Nitrate of soda, on the other hand, gradually diminishes the acidity so that plants which are much injured by the conditions naturally existing in this soil manifest eventually greater benefit from liming when sulfate of ammonia instead of nitrate of soda constitutes the source of nitrogen. In fact the conditions are such upon the unlimed plat No. 23, to which sulfate of ammonia has been applied annually for a series of years as the source of nitrogen, that many varieties of plants are unable to live there.

The acidity of the soil from the four plats previously mentioned was determined, in its natural, moist condition, in May, 1904, by the lime-water method.* The amounts of calcium oxid required per acre to neutralize the soil were found by this method to be approximately as follows:

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* See method in Wiley's Agricultural Analysis, Vol. 1, p. 331.

	Pounds.
Sulfate of ammonia plat, unlimed	4,700
Sulfate of ammonia plat, limed	1,100
Nitrate of soda plat, unlimed	2,500
Nitrate of soda plat, limed	0

The idea is frequently expressed that a treatment which decreases the humus of a soil tends to diminish its productiveness. This thought, however, should be associated with the fact that the value of humus depends upon its particular character. The limed plat receiving sulfate of ammonia, for example, contains about one-seventh less humus than the unlimed one, and yet the productiveness has been wonderfully increased by the liming. There can be no doubt, however, of the advisability of maintaining a liberal supply of organic matter of the proper kind within the soil; and, where liming proves desirable, particular attention should be given to this point, because of the tendency of the lime to decrease the organic material. Unless stable manure is applied, or an occasional green crop or grass stubble is turned under, the amount of organic matter in the soil may become depleted to such an extent in the course of time as to seriously decrease the productiveness of the soil.

The exclusive use of chemical manures for long periods of years should not be resorted to without a very careful consideration of the question of the maintenance of sufficient decomposing organic matter within the soil to conserve moisture, insure a proper physical condition, liberate plant food, and so forth.

It has been shown previously that not only the amounts of humus and of free humus were less upon the limed than upon the unlimed plats, but also that the proportion of free humus was less; or, in other words, the composition of the compounds of humus and inorganic matter is changed to such an extent by the liming as to materially decrease their solubility in ammonium hydroxid.

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* Veitch. Jour. Amer. Chem. Soc. 26. 661, (1904.)

Enough determinations are recorded herewith to indicate that there is a marked difference in the composition of the ash associated with the free humus of the limed and of the unlimed plats. In the case of the unlimed plats fertilized with either sulfate of ammonia or nitrate of soda, silica composed 26 and 23 per cent., respectively, of the ash associated with the free humus, while with the corresponding limed plats the per. cent. was increased to 35 and 32, respectively. On the other hand, the proportions of oxids of iron, aluminum, and phosphorus taken collectively were noticeably *less* in the ash associated with the free humus of the limed plats. It is recognized that the quantity of mineral ingredients which is precipitated together with the free humus by hydrochloric acid, and, to some extent, the composition of the same, are somewhat dependent upon the conditions of precipitation; but determinations made under similar circumstances, as these were, may be compared fairly with each other. The precentage of ash to free humus was about the same in all four soils. The color of the ash in each case indicated a large proportion of ferric oxid.

The amounts of the principal ash ingredients contained in the clear extract secured by ammonium hydroxid after the soil had been previously extracted with dilute hydrochloric acid and washed, that is, those ash constituents associated with the humus itself, were as follows:

Percentages of Certain Ingredients in the Ash Associated with the Humus. (Samples of Soil taken in 1904.)

	Phosphoric acid (P_2O_5).	Silica.	Ferric and aluminic oxids.
Sulfate of ammonia plats, unlimed..........	9	16	75
Sulfate of ammonia plats, limed............	13	3	72
Nitrate of soda plats, unlimed..............	10	16	68
Nitrate of soda plats, limed................	13	10	76

It may be seen that the ingredients mentioned above, constitute from 88 to 100 per cent. of the ash constituents associated with the extracted humus. The amount of phosphoric acid is greater in the ash from the limed plats than from the unlimed ones, whereas, in the case of silica, the reverse is true. This results in a wide difference in the relation of silica and phosphoric acid in the ash associated with the humus from the limed and from the unlimed plats.

The high percentage of ferric and aluminic oxids (apparently mostly ferric oxid) in the ash associated with the humus of these soils indicates some intimate connection between the humus and iron. In order to ascertain to what extent iron and humus will combine, the following work was undertaken. Leaf mould which had accumulated upon a rock in the forest and was, therefore, fairly free from soil admixture was extracted with a 2.5 per cent. ammonia solution. Ferrous chlorid, made by digesting an excess of nails in hydrochloric acid with exclusion of air until action had ceased, was poured in excess into the ammonia extract. Nearly all of the iron was precipitated, and no additional humus could be thrown out of the filtrate by hydrochloric acid. The precipitate was digested in dilute hydrochloric acid and, after decanting the latter, was dissolved nearly completely in dilute ammonium hydroxid. The precipitate was again thrown out from the filtered solution, by hydrochloric acid. The digestion in the same, and subsequent treatment with ammonium hydroxid as just described, were repeated several times in an attempt to remove such iron as was not intimately combined with the humus. The flasks in which the digestions were conducted were kept filled, and air was excluded quite generally, so that at least most of the iron should remain in the ferrous condition. The precipitate was finally washed practically free from acid, and dried under 90° C in a partial vacuum. The dried material was black and had a vitreous luster. It contained 11 per cent. of ash which had the following percentage composition: silica, 7; phosphoric acid, 10; ferric oxid, 83. It should be recognized that the composition of material prepared in this way will vary considerably with the extent of the digestion in hydrochloric acid.

The readiness with which iron in the ferrous condition combined with the humus in considerable quantity, and the quite generally asserted poisonous effects upon plant growth attributed to ferrous compounds, impress the thought that the less-productive, unlimed soil may contain iron in ferrous combinations with the humus.

The concentrated aqueous extract of the soil exhibited no reaction for iron with either potassium ferro- or ferricyanid. It is possible, however, that ferrous compounds may be present in the soil which are not readily soluble in water but still have a detrimental influence on the growth of plants. Koenig* mentions the different effect of ferrous oxid upon plant growth depending upon whether it is combined with silica, carbonic acid, sulfuric acid, or humous material. In the same connection a method is outlined for determining the amount of ferrous oxid in soils containing moderate amounts of humus. It consists essentially of digesting a soil in dilute sulfuric acid upon a water-bath, in an atmosphere of carbon dioxid, and titrating the solution with potassium permanganate. It was recognized that the results may be too high in the case of soils rich in humus, owing to the presence of organic matter. The soils from the unlimed and limed sulfate of ammonia plats were subjected to the above method for determining ferrous oxid. There was no satisfactory end-point upon titrating with permanganate. Even after a somewhat permanent pink color was obtained, a drop of the solution reacted at once with potassium-ferricyanid as though ferrous compounds were still in solution. It is not improbable that the organic matter in the solution interfered with the complete oxidation of the ferrous compounds. The titrations were somewhat easier to accomplish when an excess of the permanganate was added, and the same was titrated back with ammonium ferrosulfate, but they were still very uncertain. A fairly satisfactory end-point was finally secured, however, by using potassium dichromate as an oxidizer instead of the permanganate, and testing a drop of the solution from time to time with potassium ferricyanid until no color was produced. The amount of ferrous oxid determined by this modification equalled 0.46% of the air-dry unlimed soil, and 0.50% of the limed soil. It seems as though very little significance should be attached to the presence of iron in the ferrous condition when organic matter and ferric compounds exist in the same solution, as was the case in the dilute sulfuric-acid extract of the soil, owing to the possibility of the ferric compounds being reduced by the organic matter. The most that can be said is that this method affords no indications of the presence of a larger amount of ferrous compounds in the unlimed than in the limed soil. It is probable, however, that considerable amounts of iron are combined with the organic matter in such a way that it could not be brought into solution by the sulfuric-acid digestion. The failure of dilute hydrochloric acid to remove the iron from the artificially prepared humus mentioned above would indicate this. No reliable method suggests itself for determining all of the iron in the particular state of oxidation in which it is present in soils containing considerable organic matter, owing partly to the possibility that some iron in the ferric condition may be reduced by the organic matter to the ferrous condition during the analysis. If a method were available, it might be found that considerable iron in the ferrous condition is in combination with the organic matter in the unlimed soil in a form which is detrimental to plant growth. The iron which is present in an ammoniacal extract of humus is not thrown out of solution by a soluble phosphate nor by ammonium sulfid. This may be because it is combined with humous material to form a complex ion, and therefore fails to conform with the usual behavior of its simple ion.

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* Untersuchung landwirtschaftlich u. gewerblich wichtiger Stoffe, Berlin, 1898, p. 43.

SUMMARY.

Since 1893 two of the permanent experimental plats upon the Station plain have received equal amounts of nitrogen annually in sulfate of ammonia, and two others in nitrate of soda. About 3.7

tons of air-slaked lime have been applied in all to one of the plats receiving sulfate of ammonia, and to one of those receiving intrate of soda. Equal amounts of muriate of potash and dissolved bone-black have been added annually to each plat.

The amount of humus is now less in the limed than in the unlimed plats.

The amount of free humus is likewise less in the limed plats.

A smaller part of the humus is present as free humus in the limed plats.

The loss by igniting the oven-dry soil was somewhat less from the samples of the limed plats than from the unlimed ones.

The total nitrogen in the limed plat to which nitrate of soda is applied is less than the amount common to the other three plats.

In the case of the unlimed plats the one to which sulfate of ammonia has been added would require much more lime to neutralize it, according to the lime-water test, than the one which has received nitrate of soda. Upon the same basis, no further application of lime would be required for the limed plat to which nitrate of soda has been added, although the limed plat receiving sulfate of ammonia is still somewhat acid.

Most of the ash left upon destroying the separated humus and free humus by ignition is composed of iron and aluminum oxids, phosphoric acid, and silica.

In the case of the ash remaining from the free humus, that from the limed soils contained larger percentages of phosphoric acid and smaller percentages of silica than that from the unlimed soils.

Surprisingly large amounts of iron were found in the ash left from the ignition of the humus and free humus. The iron in the ammoniacal solutions of humus could not be thrown out by certain of the ordinary precipitants.

An artificial product made by precipitating the humus from an ammoniacal extract of leaf mould, by means of ferrous chlorid, contained in its oven-dry condition 11 per cent. of ash, of which 83 per cent. was ferric oxid; the remainder being phosphoric acid and silica.

If a satisfactory method were available for determining the state of oxidation of the iron associated with the organic matter of soils, it is not improbable that, where the productiveness of a soil is markedly increased by liming, the amount of iron in the ferrous condition would be found to have been decreased.

THE PHOSPHORIC ACID REMOVED BY CROPS, BY DILUTE NITRIC ACID AND BY AMMONIUM HYDROXID FROM A LIMED AND UNLIMED SOIL RECEIVING VARIOUS PHOSPHATES.*

B. L. HARTWELL AND J. W. KELLOGG.†

General Plan of the Field Experiment.

The experiment which rendered advisable the work herein recorded was begun at this Station in 1894, to determine the comparative manurial value of a number of different phosphatic materials. Some of the crop results have been reported, from time to time, in the publications of this Station, by the different persons having the experiment in charge.‡ The experiment comprises twenty two-fifteenth-acre plats, all of which have received annually liberal amounts of potash and nitrogen. The plats are grouped in pairs, one plat of each pair having received air-slaked lime and the other having received none. One pair has received no phosphatic manure since the experiment was begun; while the remaining pairs have each received a different phosphatic manure.

During the first years of the experiment an equal money value of the different phosphatic manures was applied to all of the plats; but later applications were made in such amounts that the total quantity of phosphoric acid applied to each of the phosphate plats from the beginning of the experiment was the same. It was thought when the spring application of 1899 had been made that this equalization of the amount of phosphoric acid received by each plat had been accomplished, but an error was subsequently discovered which made it necessary to apply more phosphoric acid to certain plats, so that it was not until the application was made in the spring of 1902 that each of the phosphate plats had really received, since the beginning of the trial, the same amount of phosphoric acid, namely, 98.48 pounds, regardless of its form. No phosphatic manures have been applied since to any of the plats.

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* To be presented in abstract at the annual convention of the Association of Official Agricultural Chemists, to be held in Washington, D. C., in November, 1905.

† The authors are indebted to Dr. H. J. Wheeler for many kindly criticisms of the manuscript.

‡ See Ann. Rpt. R. I. Agr. Expt. Sta., 1894, p. 122; Ann. Rpt., 1896, p. 227; Ann. Rept., 1897, p. 394, and Bull. 58, 1899.

THE SOIL SAMPLES.

In the spring of 1903, a year having elapsed since any of the plats had received phosphoric acid, it was thought advisable to collect samples of the soil for certain chemical work designed to aid in a study of the effects upon the soil of the various applications. Accordingly, in the latter part of June samples of the soil of each plat were taken. Of the many crops which had been planted across the plats the garden peas and oats were the only ones which had made any considerable growth, and had begun to feed upon the soil to any great extent.

Borings, approximately eight inches deep, which extended to the subsoil, were made at twenty-six different places in each plat, care being taken to make the borings at the same relative places so that any influence exerted upon the soil by the various plants which had at times been grown across the plats would be shared as equally as possible by all of the samples. The soil secured by the various borings from a given plat was air-dried and mixed, and a portion of the same which passed a two-millimeter sieve was used for all of the determinations recorded in this article. While the area devoted to the experiment is in general very level, there are individual plats which have at some time been slightly affected by washing, resulting in a greater or lesser proportion of fine gravel. There was very little of this gravel which was too coarse to pass a three-millimeter sieve. The amounts of material too coarse to pass a sieve with two-millimeter holes, which was used in preparing the samples for analysis, is given below for the various plats.

Plat No.	**51.**	**53.**	**55.**	**57.**	**59.**	**61.**	**63.**	**65.**	**67.**	**69.**
Per cent. of gravel...............	7	5	4	5	6	5	4	6	4	3
Plat No.	**52.**	**54.**	**56.**	**58.**	**60.**	**62.**	**64.**	**66.**	**68.**	**70.**
Per cent. of gravel...............	11	5	6	6	5	6	5	9	13	8

CHARACTER OF THE SOIL.

The soil* upon which the experiment is conducted is composed of glacial drift of granitic origin. It is underlaid by yellow silt loam resting upon alternating layers of gravel, sand, and silt, which furnish good natural drainage. The water table is from ten to fifteen feet below the surface. Hot hydrochloric acid of 1.115 specific gravity dissolves approximately 4.5 per cent. of aluminic oxid, 3.5 per cent. of ferric oxid, 0.6 per cent. of calcium oxid, and 0.15 per cent. of phosphoric acid. Only about 0.02 per cent. of calcium oxid was extracted by carbonated water. It contains from three to four per cent. of humus, of which considerable may be dissolved directly by ammonium hydroxid without previous extraction with dilute acid. The soil reacts strongly acid to litmus paper and fails to produce satisfactory yields, in the case of many crops, without an addition of lime or other alkaline materials.

COMPARATIVE YIELDS FROM THE VARIOUS PLATS.

The relative yields, in a green state, of certain of the crops grown across the plats in 1903, one year after the last application of phosphoric acid, are given below. These crops are selected, from the various ones planted in that year, because they grew fairly well, even upon the unlimed plats, and because they will be referred to later in connection with their phosphoric acid content.

*** Classified as Miami Silt Loam, by the Bureau of Soils, U. S. Dept. of Agr.**

The turnip crop, which will be considered later, made but a comparatively poor growth upon the unlimed series of plats.

Relative Yields in 1903 *from the Different Plats, Compared with that of the Unlimed Check Plat Taken as* 1.0.

KIND OF PHOSPHATE.	Golden German Millet.		Japanese Barn-yard Grass. (Panicum Crus-galli.)		Oats.	
	Unlimed.	Limed.	Unlimed.	Limed.	Unlimed.	Limed.
Dissolved bone-black	2.9	3.2	3.0	4.0	3.4	3.8
Dissolved bone.............	2.9	3.5	4.6	4.5	4.3	4.6
Dissolved phosphate rock....	3.0	2.8	4.0	4.6	4.4	4.5
Finely ground bone.........	3.1	3.3	3.9	4.3	4.4	4.8
Slag meal (Thomas phosphate).................	2.8	3.0	3.7	4.0	4.5	4.5
Floats (undissolved phosphate rock)............	2.9	3.3	3.4	3.6	3.2	4.1
Raw Redonda phosphate....	2.2	2.6	2.8	3.5	2.1	2.9
Roasted Redonda phosphate.	2.4	3.2	3.0	4.2	1.9	4.2
No phosphate..............	1.0	2.5	1.0	2.6	1.0	2.6
Double superphosphate.....	1.6	3.2	1.1	3.9	1.8	4.2

No attempt should be made to draw conclusions from the above results, except in a very general way, as to the comparative value of the different phosphates, even for the crops mentioned here; for only from eight to sixteen rows, twenty-four feet long, were grown in each case.

It would be necessary to compare results of more than one season and to study slight physical inequalities in the plats before one would be in a position to consider the comparative merits of those phosphates which are of approximately the same crop-producing value. For the purposes of this article, detailed consideration of the individual plats is unnecessary, as attention will be more largely directed to certain groups of plats which show quite different degrees of productiveness.

THE RELATIVE ACIDITY OF THE DIFFERENT PLATS.

It may be seen from the preceding table of relative yields that the crops were nearly always larger upon the limed plats, even though the plants considered grew quite well upon the unlimed soil, as compared with certain others which were tested. It seemed, therefore, that determinations of the acidity of the several plats might throw light upon the question as to which kind of phosphate is the most assimilable, since differences in the acidity of the soil, resulting from the varying effects of long-continued applications of the different phosphates, might exert as great an influence upon the growth of some plants as the differences in the assimilability of the phosphorus in certain phosphates.

The acidity of the soil of the different plats was determined by the lime-water method,* which consists in brief of adding a certain amount of water and of a standard lime-water to the soil, and evaporating to dryness over a water-bath. The residue is then transferred with 100c.c. of water to a flask, shaken frequently, allowed to subside over night, and 50 c.c. of the supernatant liquid evaporated with phenolphthalein. According to whether the pink color does or does not appear before a volume of 5 c.c. has been reached, the analyst knows if too much or too little lime-water has been added to produce neutrality, and is guided thereby in succeeding attempts to secure neutralization with different amounts of lime-water. It was found that variations in the shaking and time of standing had considerable influence upon the results, and the details were therefore kept uniform in this work.

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*Veitch: Jour. Amer. Chem. Soc. 26, (1904), 661.

Amount of Calcium Oxid Required to Neutralize the Acidity of the Air-dry Soil Which had Passed a 2 m.m. Sieve.

KIND OF PHOSPHATE.	UNLIMED.		LIMED.	
	Plat.	Calcium oxid required to neutralize.	Plat.	Calcium oxid required to neutralize.
		%		%
Dissolved bone-black	52	0.17	51	0.09
Dissolved bone	54	0.20	53	0.15
Dissolved phosphate rock	56	0.20	55	0.16
Finely ground bone	58	0.15	57	0.13
Slag meal	60	0.11	59	0.08
Floats	62	0.17	61	0.12
Raw Redonda phosphate	64	0.16	63	0.08
Roasted Redonda phosphate	66	0.18	65	0.17
No phosphate	68	0.19	67	0.12
Double superphosphate	70	0.24	69	0.19

The limed plats received air-slaked lime at the rate of one ton per acre in 1894, and a second ton April 28, 1903. When the soil samples were taken, two months later, there were small particles of the lime which had become carbonated and which were easily visible. Apparently there were no particles too small to be so discerned, for examination under the microscope revealed no effervescence with hydrochloric acid treatment unless particles visible to the unaided eye were present. These particles were easily broken up and must be considered quite assimilable, for upon other plats of similar soil, which were examined two years after liming, no such particles were present. It is evident, therefore, that a method which shall determine the additional amount of lime required to complete the neutralization of a recently limed soil, such as represented by the samples of limed soil under discussion, should account for any particles of carbonated lime which may be present. The lime-water method failed to do this, at least completely, for such particles were always present in the limed samples after they had been subjected to this method for determining their acidity.

This explains in some measure why there was not a greater difference in acidity between the plats which had received two tons of lime and the corresponding ones to which no air-slaked lime had been added.*

It may be seen by reference to the preceding table that considerable difference exists in some cases in the acidity of the soil of the different plats in both the limed and unlimed series. The plats which receive slag meal, for example, have a relatively low acidity, while the plats fertilized with double superphosphate are the most acid of them all. It is certainly evident that the acidity of the soil of the several plats is one of the factors to be considered before intelligent comparisons can be made of the relative assimilability of the phosphorus in the different phosphates.

THE EFFECT OF THE DIFFERENT PHOSPHATES UPON THE PHOSPHORIC ACID CONTENT OF THE CROPS.

In order to throw more light upon the question as to whether the percentage of phosphoric acid in the crop furnishes indications as to the assimilability of the phosphorus in the soil upon which the crop is grown, samples of a number of the crops grown across the phosphate plats in 1903 were taken and the phosphoric acid determined in them.

The oats were sampled July 27, "in the milk." As may be seen by reference to page 256, the oats made the best growth upon the limed series of plats; and as the conditions there seemed to be more congenial it was thought that the phosphoric acid determinations might be confined to the limed series. The relative yields as compared with the unlimed check plat taken as 1 ranged from 2.6 upon the limed check plat to 4.8 upon the limed plat receiving finely ground bone, and indicate a very marked difference in the assimilability of the phosphorus of the different phosphates in the limed series under consideration. The following determinations of phosphoric acid will show to what extent this difference conforms to the analysis of the crop.

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* An application of two tons per acre of air-slaked lime containing 75 per cent. of calcium oxid, is theoretically equivalent to 0.13 per cent. of the soil, accepting, arbitrarily, two and one-third million pounds as the weight of the air-dry soil per eight-inch acre.

Percentage of Phosporic Acid in the Dry Matter of Oats Cut "in the Milk," 1903.

Plat. (*Limed*).	KIND OF PHOSPHATE ADDED TO THE SOIL.	Phosphoric Acid.
51	Dissolved bone-black	0.549
53	Dissolved bone	0.633
55	Dissolved phosphate rock	0.518
57	Finely ground bone	0.590
59	Slag meal	0.560
61	Floats	0.518
63	Raw Redonda phosphate	0.462
65	Roasted Redonda phosphate	0.606
67	No phosphate	0.502
69	Double superphosphate	0.540

The largest crops of oats, namely, those from the plat receiving dissolved bone and from the one receiving finely ground bone, contained high percentages of phosphoric acid, namely, 0.633 and 0.590, respectively while the smallest crops, those from the check plat and from the plat receiving raw Redonda phosphate, contained only 0.502 and 0.462 per cent., respectively. The yields of oats in 1904, also, were much the smallest from the last-mentioned two plats, while the greatest yield was upon the plat supplied with dissolved bone, which in the preceding year produced a large crop containing the highest per cent. of phosphoric acid of all. On the other hand, the plat to which dissolved phosphate rock had been applied yielded much larger crops of oats, both in 1903 and 1904, than the plat which had received roasted Redonda phosphate, although the per cent. of phosphoric acid in the oats in 1903 from the former plat was only 0.518 as compared with 0.606 from the latter. This resulted in the actual removal by the crop of a greater amount of phosphoric acid per acre in the case of the smaller crop.

Percentage of Phosphoric Acid in the Dry Matter of Japanese Barn-yard Grass (Panicumcrus-galli) cut just Before the Plants were Ready to Drop Their Seeds, 1903.

Plat. (*Limed.*)	KIND OF PHOSPHATE ADDED TO THE SOIL.	Phosphoric Acid.
59	Slag meal	0.384
61	Floats	0.354
63	Raw Redonda phosphate	0.310
65	Roasted Redonda phosphate	0.360
67	No phosphate	0.328

With this plant, as with the oats, the smallest yields and the smallest percentages of phosphoric acid in the crops are in the cases of the check plat and the one receiving raw Redonda phosphate. The percentages of phosphoric acid in the crops from the other three plats here mentioned, however, do not differ in the same direction with the relative yields as given on page 256; for example, the largest yield from the five plats was from the one which had received roasted Redonda phosphate, although the crop from this plat did not contain the greatest percentage of phosphoric acid.

Percentage of Phosphoric Acid in the Dry Matter of German Golden Millet cut When the Seeds were Formed, but Still Green, 1903.

Plat. (*Limed.*)	KIND OF PHOSPHATE ADDED TO THE SOIL.	Phosphoric Acid.
59	Slag meal	0.411
61	Floats	0.335
63	Raw Redonda phosphate	0.244
65	Roasted Redonda phosphate	0.355
67	No phosphate	0.306

The order of the plats upon which the crops with increasing phosphoric acid content occur is the same with the millet as with the panicum crus-galli. The order of the yields upon the best three plats, however, is different for the two crops. Upon these three plats the percentage of phosphoric acid in the millet *decreased* with the *increase* of crop.

Relative Yields in 1903 *of Purple-Top, Strap-Leaf, Turnip Plants From the Different Plats, Compared with that of the Limed Check Plat Taken as* 1.0.

Plat. (*Limed.*)	KIND OF PHOSPHATE.	Relative yields of green material compared with Plat 67 as 1.0.	
		Roots.	*Tops.*
51	Dissolved bone-black	16.7	11.7
53	Dissolved bone	25.4	13.8
55	Dissolved phosphate rock	22.4	13.1
57	Finely ground bone	27.0	15.2
59	Slag meal	17.2	12.0
61	Floats	8.2	7.2
63	Raw Redonda phosphate	1.7	1.6
65	Roasted Redonda phosphate	7.8	5.4
67	No phosphate	1.0	1.0
69	Double superphosphate	22.5	12.6

It is evident from the relative yields given above that this kind of turnip is much more dependent upon readily assimilable phosphorus than the crops which have been heretofore considered; for the more available phosphates have increased the yield of roots more than twenty times that upon the check plat, and the yield of tops more than twelve times. In the cases of the millet, oats, and panicum, however, the yields upon the corresponding limed plats were in no case double those upon the limed check plat. It seemed reasonable, therefore, that there would be greater variations in the phosphoric acid content of turnips than of the other crops which have been considered, and determinations of the same which appear below were made in both the roots and the tops.

Percentage of Phosphoric Acid in the Dry Matter of the Turnip Roots and Tops, Sampled at the Time of Harvesting.

Plat. (*Limed.*)	KIND OF PHOSPHATE ADDED TO THE SOIL.	Phosphoric Acid.	
		Roots.	*Tops.*
51	Dissolved bone-black	0.673	0.610
53	Dissolved bone	0.837	0.726
55	Dissolved phosphate rock	0.716	0.624
57	Finely ground bone	0.866	0.833
59	Slag meal	0.741	0.647
61	Floats	0.526	0.471
63	Raw Redonda phosphate	0.450	0.312
65	Roasted Redonda phosphate	0.446	0.350
67	No phosphate	0.447	0.314
69	Double superphosphate	0.650	0.585

The percentages of phosphoric acid in both the roots and tops increase in practically the same order from plat to plat, so that a consideration of the percentages of the same in the tops will serve also for the roots. The growth upon the plat to which raw Redonda phosphate had been added and upon the check plat was extremely poor, due to lack of assimilable phosphoric acid, and the percentage of phosphoric acid in the same is only about 0.31. The plats which had received roasted Redonda phosphate and floats yielded only very moderate-sized crops, although much larger than the two plats mentioned above. The crop from the floats was a trifle the greater, and the percentage of phosphoric acid in the tops, 0.471, represents a considerable increase over that in the tops from the poorest two plats. While there is a marked increase in the percentage of phosphoric acid in the crops from the plats producing the larger yields, yet the yields and the amounts of phosphoric acid in the crops do not increase strictly in the same relative order from plat to plat. The largest two crops, however, those from finely ground bone and dissolved bone, contained noticeably more phosphoric acid than any of the others, namely, 0.833 and 0.726 per cent., respectively.

The range in the percentage of phosphoric acid is from 0.31 to 0.83 in the tops and from 0.45 to 0.87 in the roots, and is very striking as compared, for example, with the range of from 0.46 to 0.63 only in the oats grown at the same time across the same plats.

Plants similar to the turnip, having a poorly developed system of feeding-roots, and being very dependent upon having their phosphoric acid in a readily assimilable form, and, furthermore, containing a large amount of sap and a correspondingly large percentage of ash in the dry matter, are apparently more suitable for furnishing indica-cations, from their analysis, of the amount of readily available phosphorus in the soil, than plants similar to the oat in feeding power. The observations made by A. D. Hall* upon the Rothamsted experiments are of a similar nature, the root crops having been found to be very sensitive to a lack of mineral plant foods in the soil, while cereals were comparatively indifferent. He states that "the phosphoric acid requirements are well indicated by the composition of the ash of unmanured swedes."

The phosphate plats are now in grass for the purpose of introducing fresh organic matter; but it is hoped that they may be again devoted to miscellaneous crops in a few years, so that work may be undertaken, with the turnip, similar to that which appears so promising from a single year's experience.

THE EFFECT OF LIME UPON THE ASSIMILABILITY OF SOIL PHOSPHORUS.

The crops herein considered have been larger, almost without exception, upon the limed plats than upon the corresponding unlimed ones, the turnips even failing to make a satisfactory growth upon the unlimed plats. According to the lime-water method the applications of lime have reduced the acidity of the soil to some extent (see page 258). Numerous experiments at this Station upon soil of the same general character as that under discussion have shown that most agricultural plants produce larger crops when air-slaked lime or other alkaline material has been applied, even though liberal amounts of phosphoric acid and other plant foods, in assimilable forms, have been added.

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* Jour. Agr. Sci. I. 65 (1905).

It is important to consider in this connection, apart from the physical effect, whether the increased growth upon the limed series of plats is due mainly to a reduction in the acidity of the soil or in a considerable part to an increased development of assimilable phosphorus. If the application of air-slaked lime has no effect upon the supply of available phosphorus, but simply renders the reaction of the soil more suitable for the growth of certain plants, then the yield upon the slag-meal plat, for example, might be relatively larger, on account of the basic action of this material, than if the amount of assimilable phosphorus it contained was the only influencing factor; and the percentage of phosphoric acid in the crop might be correspondingly smaller. On the other hand, if a reduction of the acidity of the soil renders the phosphorus of the soil more assimilable, then the percentage of phosphoric acid in the crop from the less acid plats, other things being equal, might be increased.

Certain results follow which indicate that the lime may tend to increase, in some cases, the amount of available phosphorus. The crop of turnip roots from the limed plat which had received finely ground bone was 62 per cent. greater than from the corresponding unlimed plat, and the per cent. of phosphoric acid in the dry matter of the roots was 0.866 from the limed plat and 0.804 from the unlimed one. Again, the increase in the crop of turnip roots from the limed plat to which slag meal had been added was 34 per cent. as compared with the unlimed plat, and the phosphoric acid in the dry matter of the roots was 0.741 per cent. from the limed plat and 0.708 per cent. from the unlimed one. These increases in the percentage of phosphoric acid in the turnip roots grown upon the limed plats furnish some evidence that more of the phosphorus in these plats was assimilable.

In order to secure a hint as to the action of lime upon the phosphorus of the soil of the Station plain, a sample was taken from plats contiguous to those upon which the phosphate experiment is conducted; this was air-dried for a few days and sifted through a millimeter sieve. The soil then required, according to the lime-water method, 0.20 per cent. of calcium oxid to neutralize it. Four 65-gram portions were weighed out; to one portion nothing was added; to the second 0.7429 gram of hydrated lime was added (about 10 tons per acre); to the third, 0.1486 gram of c. p. sodium nitrate and 0.1486 gram of c. p. potassium sulfate (about 2 tons each per acre); and to the fourth, 0.7429 gram of hydrated lime in addition to the same amount of sodium nitrate and potassium sulfate as was added to the third portion. After thorough mixing, each portion was placed upon a double filter in a funnel, covered with a piece of filter paper to prevent puddling, and leached at the same time as the others with 20 c. c. portions of distilled water until 250 c. c. of extract was obtained. The leaching was done during the business hours between the middle of the afternoon and noon of the following day. The extracts were perfectly clear. They were evaporated in porcelain dishes and the residues ignited. Upon ignition of the residues there was considerable evidence of organic matter in the cases of the limed portions. The acid extracts from the four residues were tested with molybdic mixture in the usual manner, the volumes being equal in all cases, so that the amounts of phosphoric acid from the original portions to which lime was added could be compared with those from the portions to which no lime was added without the necessity of making quantitative determinations of such small amounts. The relative amounts of ammonium phosphomolybdate, as indicated by color and precipitate, left no doubt about there being more phosphoric acid in the extracts from the portions to which the hydrated lime had been added than in the others. This difference was quite marked, both in the comparison upon the natural soil and when sodium nitrate and potassium sulfate had been added. The trial was carried through again subsequently with the same results. A blank determination was made with the sodium nitrate, potassium sulfate, and hydrated lime, but no phosphoric acid was obtained. The above results suggest that some of the benefit derived from liming the Station soil is probably due to the liberation of an increased amount of phosphorus whenever there may be a lack of the same; and that a consideration of the availability of phosphorus in different phosphates, and of the percentage of the same in the crops, should be accompanied with a recognition of the varying effects of different phosphates upon the reaction of the soil.

THE EFFECT OF THE NITROGEN ASSOCIATED WITH BONE PHOSPHATES.

It may be seen by reference to pages 260 and 263 that the percentages of phosphoric acid in the crops from the plat which had received dissolved bone and from the one to which finely ground bone was added in the cases of the two crops analyzed, namely, oats and turnips, were greater, with one exception, than upon any other plats; the highest yields also were from these plats. Such a liberal amount of nitrate of soda was added annually to all of the plats that no deduction was made for the additional amount of nitrogen contained in the dissolved bone and finely ground bone. In view, however, of the large yields from these plats, nitrogen determinations were made in the turnip roots and tops from the same, and also from contiguous plats whose source of phosphorus contained no nitrogen. Had more nitrogen been found in the crops fertilized with the phosphates which had nitrogen accompanying them, namely, the bones, a hint would have been obtained that possibly the extra nitrogen played an important part, as plant food, in the production of the greater crops. Instead of there being more nitrogen, however, there was generally less, as shown below.

Percentage of Nitrogen in the Dry Matter of the Turnip Roots and Tops.

Plat. (*Limed.*)	KIND OF PHOSPHATE ADDED TO SOIL.	Roots.	Tops.
53	Dissolved bone	2.14	3.39
55	Dissolved phosphate rock	2.20	3.72
57	Finely ground bone	2.51	3.70
59	Slag meal	2.85	4.06

THE PHOSPHORUS ASSOCIATED WITH THE ORGANIC MATTER OF THE SOIL.

The field experiment under consideration furnished an exceptionally good opportunity for studying the solubility, in different solutions, of the phosphorus in the various plats, to ascertain if the amounts dissolved indicated to any extent the relative productiveness of the plats.

A large part of the phosphorus in the soil where the experiment was conducted is associated with the humus. The *total* phosphoric acid was determined in soil from four different experimental plats upon the plain (Nos. 23, 25, 27 and 29), after igniting the soil to render any phosphorus, which might be associated with the humus, soluble in acid and then digesting in strong hydrochloric acid. The insoluble silicious material was treated with sulfuric and hydrofluoric acids to volatilize the silica, and the residue dissolved in strong hydrochloric acid so that any phosphorus which might have formed insoluble combinations with the silicious material could be included with that from the first extraction. The average of the four determinations was 0.26 per cent. of phosphoric acid. Had the solutions been prepared by the usual digestion in hydrochloric acid of 1.115 specific gravity, without previous ignition, this amount would undoubtedly have been considerably less; for it has been repeatedly shown that, in soils having a large proportion of their phosphorus in organic combinations, a considerable amount fails to be obtained by simply digesting in hydrochloric acid. The phosphoric acid which was associated with the total humus of the same samples averaged 0.13 per cent., or one-half of the total amount in the soil.

Snyder says* "humic phosphoric acid is * * * one of the most valuable forms of available phosphoric acid," and it certainly seems reasonable that a considerable portion of the assimilable phosphorus in certain soils is developed from the humates. The weak acid solutions, however, which have been found in many instances to dissolve from soils amounts of phosphorus bearing similar relations to the productiveness of those soils, exert practically no solvent effect upon the phosphorus associated with the humus. Snyder,* for example, digested a soil for three months with a one per cent. citric-acid solution, without decreasing the amounts of phosphorus associated with the humus and with the precipitated humus.

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* Bul. 53, Minn. Exp. Sta., page 32.

The greater number of the attempts which have been made in the past to determine the assimilable mineral ingredients of soils have been carried out with solvents which had little effect upon the portions of those ingredients which are combined with organic matter although much evidence has been obtained that some relation exists between the productiveness of certain soils and the mineral ingredients associated with the humus which are brought into solution by alkaline solvents attacking the organic matter. The Hilgard method for soil analysis includes the determination of the phosphoric acid in the ash of the humus, and it is reported as "soluble phosphoric acid." Hilgard says, "a very striking agreement with actual practice is often found in making this determination."

Huston†, after working with an ammonium oxalate solution supplemented on the one hand by ammonia and again by acid, with citric acid alkaline and neutral ammonium chlorid, and with ammonia of 0.96 sp. gr. at room temperature, decided upon the latter as giving promising results in connection with the determination of assimilable phosphoric acid, and stated that "the results clearly distinguished the lands poor in phosphoric acid from those known to be well supplied with available phosphoric acid." More recently Veitch‡, in connection with the use of $\frac{n}{100}$ hydrochloric acid, remarks that the phosphorus of organic matter is apparently but little affected by this acid, and states: "it appears desirable to study the solvent effect of more concentrated acids, at the same time endeavoring to reach the phosphorus in organic combination."

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* Bul. 65, Minn. Exp. Sta., page 63.

† Bul. No. 49, Div. of Chem. U. S. Dept. of Agr., (Proc., A. O. A. C. '96) page 95.

‡ Bul. No. 81, Bur. of Chem. U. S. Dept. of Agr., (Proc. A. O. A. C. '03) page 138.

THE RELATIVE AMOUNTS OF PHOSPHORUS EXTRACTED BY NITRIC ACID AND BY AMMONIUM HYDROXID.

To gain some idea of the relative amounts of phosphorus in the soils in question which are soluble in dilute acid and in ammonium hydroxid, a few preliminary tests were made. The conditions of digestion were uniform in all of the work recorded in the succeeding pages, and were as follows: 200 grams of the air-dry soil which had passed a two-millimeter sieve were added to two liters of the solvent contained in a two-and-one-half liter, glass-stoppered bottle, after the temperature of the solution had been brought to 40° C. by immersion in a water-bath. The temperature of the solution was maintained at from 40° to 44° for five hours, agitating the bottle every half-hour by inverting it twelve times. The solution was then decanted through a filter, and from 1,700 to 1,900 c.c. of the clear filtrate evaporated for the gravimetric determinations. The silica which had been rendered insoluble was volatilized with hydrofluoric acid so that any phosphorus which might have been retained by it was secured. The ammonium phosphomolybdate was reprecipitated to secure a better separation from the iron and aluminum in the cases of digestion with acid.

Samples of soil from four of the limed plats, Nos. 55, 61, 63, and 67, were digested with $\frac{n}{5}$ nitric acid and the percentages of phosphoric acid in the extract were, respectively, 0.0140, 0.0160, and 0.0144 for the first three, the average being 0.0146. The fourth solution was lost. The residues from the above extraction were washed with distilled water until the same remained neutral and then digested with $\frac{n}{5}$ ammonium hydroxid. The percentages of phosphoric acid obtained by this extraction were, respectively, 0.0774, 0.0953, 0.0796, and 0.0788, or an average of 0.0828. That is, less than one-fifth as much phosphoric acid was obtained by extracting the soil with $\frac{n}{5}$ nitric acid as was obtained by a subsequent extraction with the same strength of ammonium hydroxid. Determinations with $\frac{n}{25}$ solutions were made upon the same samples in the same manner as above.

The percentages of phosphoric acid dissolved by the $\frac{n}{25}$ nitric acid were, respectively, 0.0024, 0.0039, 0.0006 and 0.0017, or an average of 0.0022; and the subsequent extraction with $\frac{n}{25}$ ammonium hydroxid gave, respectively, 0.0312, 0.0394, 0.0254, and 0.0310 per cent. of phosphoric acid, an average of 0.0315 per cent., or more than fourteen times as much as was dissolved by the preliminary extraction with the acid. These results indicate that dilute alkaline solutions dissolve much more phosphorus from the soils in question than dilute acid of the same strength.

To ascertain the action of dilute ammonium hydroxid upon the soil not previously extracted with nitric acid, and to secure some hints as to the most desirable strength to use in an attempt to determine the more easily attacked phosphorus associated with the organic matter, soil from plats 54 and 64 (unlimed) were digested directly with $\frac{n}{5}$ ammonium hydroxid; 0.0395 and 0.0314 per cent., respectively, of phosphoric acid were obtained. These amounts, while differing in the same direction as the relative productiveness of the two plats, are too nearly alike to be of service in this connection, for the quantity of oats produced in 1903 was about twice as large upon the former plat as upon the latter. Furthermore, the percentage of phosphoric acid dissolved was too great to be considered as representing the assimilable portion. Soils from two plats, Nos. 56 and 68, upon which the relative yields of oats were as three to one in 1903, were next digested directly with a weaker solution of ammonium hydroxid, $\frac{n}{25}$, with the result that 0.0184 per cent. of phosphoric acid was extracted from the former and 0.0250 per cent. from the latter, or in reverse order to the yield of oats. Here again the amount of phosphoric acid dissolved is quite large, and a few preliminary determinations were made, using $\frac{n}{100}$ ammonium hydroxid, which showed sufficient agreement with crop results to warrant other determinations of the amount of phosphoric acid dissolved by this strength of ammonium hydroxid. The filtrates from this digestion were alkaline to methyl orange, and nearly neutral to litmus. The results are recorded in the following table:

Per Cent. of Phosphoric Acid Extracted by $\frac{n}{100}$ Ammonium Hydroxid.

KIND OF PHOSPHATE ADDED TO THE SOIL.	Unlimed.	Limed.
Dissolved bone	0.0040	0.0036
Slag meal	0.0031	....
Floats	0.0044	0.0038
Raw Redonda phosphate	0.0030	0.0018
Roasted Redonda phosphate	0.0054	0.0032
No phosphate	0.0068	0.0033

There is no general agreement between the above results and the productiveness of the various plats. The amount of phosphoric acid dissolved from the soil of the unlimed check plat is noticeably high. The percentage of phosphoric acid removed from the unlimed soils by the ammonium hydroxid is always greater than from the corresponding limed ones. The humus of the unlimed soils was likewise always dissolved to a greater extent by the direct treatment with the ammonium hydroxid without the previous extraction with acid as required in total-humus determinations.

It has been the general experience at this Station that liming decreases the amount of so-called free humus, *i. e.*, the portion directly soluble in ammonium hydroxid; in fact, the intensity of the dark extract by this solvent has come to be regarded as a suggestion of the amount of lime desirable to apply. It was not known, however, to what extent the phosphorus was associated with this particular portion of the humus. The amount of humus directly extracted by the $\frac{n}{100}$ ammonium hydroxid from five of the limed plats varied between 0.337 and 0.363 per cent., with an average of 0.350; the variation in the case of the corresponding unlimed plats was from 0.359 to 0.399 per cent., with an average of 0.378. It is an interesting fact in this connection that not only was there more humus directly soluble in $\frac{n}{100}$ ammonium hydroxid from the unlimed than from the limed plats, but that the percentage of associated phosphoric acid in the humus was also greater in each of the five cases where comparisons were made.

THE SOLVENT ACTION OF DILUTE ACID UPON THE SOIL PHOSPHORUS.

C. C. Moore* attempted to find a strength of hydrochloric acid which would remove approximately the same amount of phosphoric acid and potash from a soil as one crop of oats grown in pots. The conditions finally adopted by him for the extraction were as follows: 200 grams of soil; one liter of acid of such strength that it would be $\frac{n}{200}$ to methyl orange at the end of the digestion; a temperature of 40° C; digestion for five hours in a shaking machine. A preliminary digestion with a small amount of soil, using methyl orange as an indicator was carried out to ascertain what strength of acid was necessary at the beginning of the digestion in order to have $\frac{n}{200}$ acid at the end. This investigation was very comprehensive, including a large number of soils, both virgin and cultivated, from widely different localities. It seemed that our phosphate experiments afforded an excellent opportunity for testing the capabilities of this method, in the case of fertilized soil, for determining the amounts of assimilable phosphoric acid in the various plats, especially as young oat plants were growing upon the plats at the time the soil was sampled, and the phosphoric acid removed by the crop could be compared with that removed by the $\frac{n}{200}$ acid. It should be recalled, in this connection, that the plats were liberally fertilized with nitrogen and potash, so that the yield would be expected to depend upon the amount of phosphoric acid which the plants were able to secure from the various phosphates, and also that no phosphoric acid had been applied to any of the plats since the year preceding the one in which the samples of soil were taken.

The Bureau of Chemistry of the Department of Agriculture at Washington kindly consented to determine the phosphoric acid in the soils by the $\frac{n}{200}$ hydrochloric-acid method, as the Rhode Island Station was not equipped with a shaking machine and constant temperature oven, which would enable us to follow the method under the same conditions worked out by Moore at Washington. Our thanks are rendered here for this assistance. Sub-samples of the soil, representing exactly the samples upon which the other chemical work herein recorded was done, were forwarded to the Bureau of Chemistry. Circumstances prevented the Bureau of Chemistry from making the determinations of phosphoric acid in all twenty of the samples, but fortunately the ones upon which the determinations were made were from plats Nos. 51 to 60, inclusive, and represented the ones to which some of the best forms of phosphates had been added the year previously, viz.: dissolved bone-black, acid phosphate, dissolved bone, finely ground bone, and slag meal, with and without lime. Excellent crops of oats were produced upon these plats, especially upon those to which lime was added, during the season of 1903, at the beginning of which the soil samples were taken, and again in 1904 without further addition of phosphoric acid. Nevertheless, Moore writes as follows concerning the soils: "I digested them in the equivalent of $\frac{n}{200}$ hydrochloric acid and got no phosphoric acid. I have stated that the suggested scheme of analysis was probably not applicable to fertilized soils inasmuch as the conditions are altogether changed." As the method gave *no* phosphoric acid in the samples representing the best plats, it of course was not adapted for determining differences in the amount of assimilable phosphorus in the plats under consideration. If the experience gained heretofore at Washington with pot culture regarding the ability of the oat crop and the $\frac{n}{200}$ hydrochloric acid to remove similar amounts of phosphoric acid from virgin soils were to serve as a guide under our field conditions, it would have been expected that a comparatively liberal amount of phosphorus should have been dissolved, considering the excellent crops which were produced upon these plats and the large amount of phosphorus removed by them. Evidently the method is not adapted under our field conditions to soil such as the one which is receiving artificial manuring at this Station.

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*Jour. Am. Chem. Soc. 24, 79 (1902).

It was learned subsequently that phenolphthalein instead of methyl orange was incidentally used in these particular determinations, which may explain, as indicated later, why no phosphoric acid was obtained.

F. P. Veitch, referee on soils for the Association of Official Agricultural Chemists in 1903, recommended the $\frac{n}{200}$ hydrochloric-acid method for co-operative work *without* increasing the strength of the acid by an amount equivalent to that neutralized by the soils, and later made the following statement in his report: "From these results it appears that the $\frac{n}{200}$ acid method when not corrected for basicity extracts less phosphoric acid from most soils than is removed by crops." He also points out the desirability of studying the solvent effect of more concentrated acid than the $\frac{n}{200}$

A few years ago $\frac{n}{5}$ hydrochloric acid was adopted provisionally by the Association of Official Agricultural Chemists "for the determination of the more active forms of the phosphoric acid in soils," and has not been abandoned since. Fifth-normal nitric acid has been shown to yield practically the same results, and determinations were therefore made with this solvent in samples from plats of widely different productiveness, namely: the limed plats to which dissolved phosphate rock, floats, and raw Redonda phosphate had been added. The relative yields of turnip roots from these plats in 1903 were 22.4, 8.2, and 1.7, respectively, compared with the check plat at 1.0. The percentages of phosphoric acid removed from the soil by the $\frac{n}{5}$ acid were 0.0140, 0.0160, and 0.0144, respectively. These amounts bear no relation to the crop results.

Preliminary trials with $\frac{n}{25}$ nitric acid, however, promised a little better, for the poorest two limed plats gave only 0.0006 and 0.0017 per cent. of phosphoric acid, whereas two plats of greater productiveness yielded 0.0024 and 0.0039 per cent. It was decided to make determinations in a number of the samples with this strength of acid, especially as a similar strength had been recommended by certain European chemists for such work. The initial strength of acid used upon all of the samples was the same; it was thought that this would admit of fair comparisons being made among the plats on the limed side; and again among those upon the unlimed side.

The results are given below:

Percentage of Phosphoric Acid Extracted by $\frac{n}{15}$ Nitric Acid.

KIND OF PHOSPHATE ADDED TO THE SOIL.	Unlimed.	Limed.
Dissolved bone	....	0.0029
Dissolved phosphate rock	0.0038	0.0024
Finely ground bone	0.0029	0.0026
Slag meal	0.0027	0.0017
Floats	0.0042	0.0039
Raw Redonda phosphate	0.0020	0.0006
Roasted Redonda phosphate	0.0038	0.0014
No phosphate	0.0052	0.0015

It may be readily seen that the first column of figures throws no light upon the amount of assimilable phosphoric acid in the unlimed plats. (Reference should be made to page 256 for the relative yields of certain crops upon the various plats.) The check plat gave the largest percentage of any, 0.0052, and produced the smallest crop. The plat receiving roasted Redonda phosphate gave only a fair crop compared with the first three which are accompanied above by the phosphoric acid percentages in the "unlimed" column, and yet as large an amount of phosphoric acid was obtained from it as from the first of the three plats just mentioned, and larger than from the two others.

With the limed plats there is a somewhat better agreement. (Reference may be made, also, in this case to the relative yields of turnips from these plats given on page 262, as this crop grew normally upon the limed plats when sufficient assimilable phosphorus was present.) The last three percentages in the "limed" column are the smallest, and they are from the poorest plats; but the plat to which floats had been added previously gave only a medium crop, although the percentage of phosphoric acid, 0.0039, is the largest from any of limed plats. It is possible that the acid was more largely neutralized in the case of the sample from the plat receiving slag meal, owing to the alkaline nature of this material, and that the percentage of phosphoric acid, 0.0017, is on this account lower than from the three others above it, with which it should be classed from the standpoint of crop production. Considering the relatively small difference in the amounts of phosphoric acid extracted by the $\frac{n}{25}$ acid from the poorest and from the best plats, as compared with the very large differences in the amounts removed by the crops, the method does not appear of much value for determining even the relative amounts of phosphoric acid at the disposal of the plants under the conditions of the experiment.

It may be seen from the foregoing table that the amount of phosphoric acid extracted was always greater from the unlimed than from the limed plats. In order to ascertain if this was probably due to the difference in the strengths of the acid at the end of the digestion, caused by the added lime, an attempt was made in two instances to so change the strength of the initial acid that the solutions after the digestion of the samples of the limed and corresponding unlimed soil would be of about the same acidity as shown by methyl orange.

The soil from the unlimed plat receiving roasted Redonda phosphate was accordingly digested with a weaker acid than the $\frac{n}{25}$, so that the solution at the end of the digestion was about the same as from the corresponding limed soil; with the result that the percentage of phosphoric acid was reduced from 0.0038 to 0.0015, or to practically the same as from the limed plat. In another instance, with the samples from the no-phosphate plats, the strength of the solution was increased in the case of the limed sample to make its final strength about the same as that from the unlimed one. The percentage was increased thereby from 0.0015 to 0.0035. This is less, to be sure, than was obtained from the corresponding unlimed soil, namely, 0.0052, but taken with the results given above, from the plats receiving roasted Redonda phosphate, indications are furnished that, with strict attention to the equalization of the acidity at the end of the digestion, practically the same amount of phosphoric acid would have gone into solution from the corresponding limed and unlimed soils.

In a given series, limed or unlimed, there were some differences among the various plats in the final acidity of the solution when tested with methyl orange, and in view of the considerable effect of a change in the strength of acid upon the amount of phosphoric acid dissolved, as shown by the above results, notice was taken as to whether these differences might be the reason for the failure of the $\frac{n}{5}$ acid to remove amounts of phosphoric acid comparable with the crop production. It was found, however, that the differences were not sufficiently great nor in such a direction as could account for the lack of agreement with the crop results.

According to some investigators quite wide variations in the strength of dilute nitric acid have exerted very little effect upon the amount of phosphoric acid dissolved, the contention being that the dilute nitric acid acted principally upon the phosphates of the alkalies or alkaline earths, and that a very considerable increase in the strength of the acid could be made before the phosphoric acid in the more insoluble combinations with iron and aluminum would be attacked to any great extent. Moore's* results with dilute hydrochloric acid, however, show that with many soils no such uniformity exists in the amount of phosphoric acid dissolved. The results by T. Schloesing, Jr.,† in this connection are very interesting. He digested about 20 grams of soil in about one liter of dilute nitric acid of varying strengths for ten hours at room temperature, with constant agitation, and found that about equal amounts of phosphoric acid were dissolved from a given soil when the final acidity of the solution was anywhere between one and two parts of nitrogen pentoxid in ten thousand up to one part in a thousand. This latter strength equals about $\frac{n}{50}$ nitric acid. With this dilute acid scarcely any iron was brought into solution; but as the greater strength of acid was exceeded the amount of iron increased and the amount of phosphoric acid no longer remained constant.

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*Jour. Am. Chem. Soc. 24, 92, (1902.)

†Compt. Rend. Acad. Sci. Paris, 128, 1004 (1899), Abs. Centbl. Agr. Chem. 29, 79, (1900.)

The final acidity of the solutions after digestion with $\frac{n}{25}$ nitric acid was in our case from $\frac{n}{50}$ to $\frac{n}{90}$ in round numbers, using methyl orange as an indicator, and $\frac{n}{26}$ to $\frac{n}{31}$ with luteol*, the acidity being somewhat less when the limed soil instead of the unlimed soil was digested. It is presumed that the indicator used by T. Schloesing, Jr., although not mentioned in the articles referred to, took into account simply the reduction in the acidity caused by the stronger bases in the soil, and that the final acidity of our solutions as determined by luteol would therefore furnish a better basis for comparisons. Viewed from this standpoint the final acidity where we used $\frac{n}{25}$ nitric acid was greater than that found, by T. Schloesing, Jr., to be capable of exerting a solvent action upon the iron compounds, although according to the acidity determined by methyl orange, our solutions were within the range of acidity found by him to give a constant amount of phosphoric acid and practically no iron. It should be recalled that our conditions for digestion and the proportion of soil to solvent were different from those of T. Schloesing, Jr., and that any comparisons made with results secured by this method should be viewed accordingly. Nevertheless, in view of the quite extensive work done by A. de Sigmond† with the Schloesing method, such comparisons seem warranted to a certain extent. T. Schloesing, Jr., extracted by this method from four different soils about 0.010, 0.018, 0.025, and 0.175 per cent. of phosphoric acid with nitric acid having a final acidity somewhat less than $\frac{n}{50}$. Sigmond under similar conditions, by the same method, secured only traces from two soils and percentages of phosphoric acid ranging from 0.013 to 0.159 in seven other soils, and finds, by comparison with results secured by the growth of plants in pots, that as a rule soils containing over about 0.075 per cent. of phosphoric acid soluble in the dilute nitric acid were not benefited by phosphates, although it was not always true that soils yielding less than this amount were in need of phosphatic fertilizers.

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* It was found by trial with the soil solutions that the titrations with ammonia using luteol as an indicator were about the same as with potash using phenolphthalein, so that the former was used in our case for convenience.

†Ann. Sci. Agron. **16**, II, 451, (1900.)

The amounts of phosphoric acid secured by the Schloesing method of digestion from the soils considered above are, as may be noticed, much greater, as a rule, than were obtained by us from the soil of the phosphate experiment; for the maximum amount in our case was only about 0.005 per cent., while as a rule not more than 0.003 per cent. was secured. The percentages of combined ferric and aluminic oxids, however, obtained by us with $\frac{n}{25}$ nitric acid vary from 0.38 to 0.59 per cent. among the various plats, while the three soils in which T. Schloesing, Jr., determined the ferric oxid, obtained by digestion in nitric acid of about the same final acidity, contained only about 0.02, 0.05, and 0.01 per cent., or a tenth as much as our soil yielded. It is quite probable that the ferric oxid recorded by T. Schloesing, Jr., included also any aluminic oxid which may have been present, although this point is not discussed, for his main object in making this determination was to indicate at what strength of acid the phosphates which are more insoluble than the alkaline earth phosphates went into the solution, and the aluminum as well as the iron phosphates would be included in this class. It seems quite evident that the soil from our phosphate experiment yielded much more iron and aluminum and less phosphoric acid, to the action of dilute nitric acid, than those investigated by T. Schloesing, Jr.

As was stated before, the final acidity of the solution obtained by us by digesting the soil in $\frac{n}{25}$ acid was somewhat greater than recommended by T. Schloesing, Jr., in case he used an indicator similar to phenolphthalein, whereas if he used an indicator similar to methyl orange, our strength of acid was within the limits established by him. In order to be certain to have the amounts of iron and aluminum oxids secured by an acid within the same limits of strength as recommended by Schloesing, a few determinations were made of the amount dissolved by dilute nitric acid having an initial acidity of $\frac{n}{75}$. The *final* acidity by luteol varied from $\frac{n}{75}$ to $\frac{n}{125}$

among the four different plats tested, and was therefore within the limits fixed by Schloesing ($\frac{n}{50}$ to five or ten times this dilution) if viewed from the standpoint of this indicator. Even this very dilute acid dissolved a surprisingly large amount of aluminum oxid from the soils. There was practically no iron dissolved, not enough to impart a yellow tint to the aluminum hydroxid precipitate. The average amount of oxid from the four samples was 0.195 per cent. Aluminum may therefore exert an important influence in the neutralization of even very dilute acid, and this fact must be considered in the selection of an indicator designed to determine the free acidity of the final solution. A small amount of phosphoric acid was obtained in each case, but the difficulties attending a correct gravimetric determination of so small an amount in the presence of so much aluminum deterred us from attempting it. Attention should be called to the fact that the final acidity by methyl orange for the four soils was $\frac{n}{172}$, $\frac{n}{235}$, $\frac{n}{356}$, and $\frac{n}{416}$, respectively; and yet, in spite of the fact that the dilution was generally greater than recommended in the Moore method of digestion, small amounts of phosphoric acid were obtained in each case. As mentioned before, Moore obtained no phosphoric acid from these soils when phenolphthalein was used as an indicator in ascertaining the neutralizing power of the soil.

THE CHOICE OF INDICATORS.

The selection of an indicator for determining the final acidity of a dilute acid solution in which soil has been digested is in many cases a matter of considerable importance and demands more attention than has sometimes been given to it. Phenolphthalein, a weak acid indicator, has sometimes been employed; and again, methyl orange, one of the strongest acid indicators, with no apparent consideration of the great differences in results, which may, in certain cases, arise with the two indicators. The Association of Official Agricultural Chemists, in its "provisional method for the determination of the more active forms of the phosphoric acid in soils," recommends phenolphthalein as an indicator in ascertaining, by a preliminary digestion, the amount of acid which is neutralized by the soil in order that a final acidity of $\frac{n}{5}$ may be secured. The original object of this preliminary digestion was probably to enable the method to be used with calcareous soils by increasing the acid by an amount which the lime of the soil was capable of neutralizing. Phenolphthalein, being sensitive to lime, was for this purpose an allowable indicator to employ. The situation changes, however, when a soil yielding much iron and alumina to dilute acid is analyzed; for these weaker bases certainly decrease the acidity in such a case, although phenolphthalein is incapable of measuring this decrease because it is not suitable for titrating such weak bases. The average amount of combined ferric and aluminic oxids dissolved from the soil of three of the limed plats by $\frac{n}{5}$ nitric acid was 1.456 per cent., while only one-tenth this amount, 0.146 per cent., of calcium oxid was dissolved, even though the plats had received, in previous years, two tons of air-slaked lime per acre. The average amount of silica was 0.265 per cent., and of phosphoric acid 0.015 per cent. Owing to the comparatively small amount of phosphoric acid its relative effect upon the two indicators mentioned may be left out of consideration. The silica and sesqui-oxids have, of course, different relative effects upon these indicators, but in view of the relatively large amount of the sesqui-oxids present in this case, to which methyl orange is sensitive and phenolphthalein is not, it is probable that the principal difference in the action of the two indicators may be attributed to the presence of the oxids of iron and aluminum in solution.

The extracts from digesting the soils of the various plats in $\frac{n}{25}$ nitric acid were titrated with $\frac{n}{14}$ ammonium hydroxid, using methyl orange and luteol as indicators. (As has been said, the latter indicator gave readings, with potash solution, similar to phenolphthalein.) The results show the remarkable differences which occur in such solutions with indicators of strong and weak acid properties. The final acidity as shown by the average of all of the samples being with luteol $\frac{n}{28}$, while with methyl orange it was only $\frac{n}{66}$. Again, four samples were digested in $\frac{n}{75}$ nitric acid, the average acidity after digestion being $\frac{n}{95}$ with luteol and $\frac{n}{370}$ with methyl orange; these solutions contained on an average about 0.19 gram of aluminum oxid per liter.

In the original article by Moore, previously cited, in which hydrochloric acid of a final acidity of $\frac{n}{200}$ was recommended, methyl orange was prescribed as the indicator; whereas in the co-operative work with this solvent, upon the samples furnished from our phosphate plats, according to which no phosphoric acid was obtained, phenolphthalein was used as the indicator. It seems probable, from our results with nitric acid and the same soils, that, had methyl orange been used as the indicator in the preliminary determination for ascertaining the neutralizing effect of the soil upon the acid, an acid two or three times stronger would have been necessary in order to secure a final acidity of $\frac{n}{200}$. In which case it is possible that amounts of phosphoric acid bearing some relation to the productiveness of the plats might have been obtained, as was the case with the soils from various parts of the country examined earlier by the Bureau of Chemistry with $\frac{n}{200}$ hydrochloric acid, using at that time methyl orange as the indicator.

In order to gain further information regarding the relative sensitiveness of methyl orange and luteol to aluminum, a dilute solution of potassium-aluminum sulfate was titrated against a standard ammonium hydroxid solution. With methyl orange as an indicator the change of color began when a few tenths of a c.c. of the alkali had been added, while with luteol over 14 c.c. had to be added before the change of color occurred, which amount approached what would have been required by a quantity of sulfuric acid equal to that combined with the aluminum of the alum. In other words, luteol is not sensitive to aluminum, and, like phenolphthalein, is unsuitable for measuring the neutralizing effect of such weak bases upon the dilute acid used in soil digestion. It need scarcely be said that cochineal, which is so largely used in nitrogen determinations, is wholly unsuitable because of the pink color which iron and aluminum impart to it, resembling the change caused by an alkaline solution.

SUMMARY.

Owing to the marked influence of the reaction (acid or alkaline) of the soil upon the growth of certain plants, the effect of the different phosphatic materials upon this reaction must be considered in connection with a study of the assimilability of the phosphoric acid in those phosphates.

The assimilability of the phosphates themselves, and of the phosphorus of the soil, varies with the reaction of the soil.

The range in the percentage of phosphoric acid in oats, golden German millet, and Panicum crus-galli, fertilized with different phosphates, was not wide enough to serve as a measure of the assimilability of the phosphorus in different materials.

The results with flat turnips, however, indicate that this plant may serve a useful purpose in testing the relative assimilability of the phosphates.

The relative yields of turnip roots upon the limed phosphate plats, all of which had received the same amount of phosphoric acid, ranged between 1.7 and 27.0, depending upon the kind of phosphate, as compared with the limed check plat taken as 1.

The percentage of phosphoric acid in the dry matter of the turnip roots varied between 0.45 and 0.87; and in the tops, between 0.31 and 0.83.

The general tendency was for the percentage of phosphoric acid in the turnip crop to increase with the increase in the size of the crop brought about by the better kinds of phosphates.

It is possible that the percentage of phosphoric acid in the turnip may indicate the relative amounts of assimilable phosphoric acid in different soils, when certain conditions are well understood.

Half of the total amount of phosphorus in this soil is extracted with the humus. Much greater amounts of phosphorus were extracted from the soil with dilute ammonium hydroxid than by the same strengths of nitric acid.

Ammonium hydroxid of $\frac{n}{5}$, $\frac{n}{25}$, and $\frac{n}{100}$ strengths did not extract amounts of phosphorus in good accord with the assimilability of the phosphorus in the different plats. Fifth-normal and $\frac{n}{15}$ nitric acid also failed to uniformly point out the differences in the assimilability of the phosphorus as shown by the crop results.

The selection of an indicator for determining the neutralizing properties which a soil exerts upon an acid in which it is digested is of considerable importance, in view of the widely differing results secured by indicators of such different classes as methyl orange and phenolphthalein.

It is doubtful if any solvent will extract from all soils amounts of phosphorus bearing definite relations to those removed by even a given crop. This is especially true when a large portion of the total amount of this element is in combination with organic matter and must depend, therefore, to a considerable extent, upon the microorganisms of the soil for its liberation.

ON THE CAUSES OF UNPRODUCTIVITY IN A RHODE ISLAND SOIL.

BY

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IN CO-OPERATION WITH

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INTRODUCTION.

(BY H. J. WHEELER).

The following paper gives an account of some cooperative work between the Rhode Island Station and the Bureau of Soils of the U. S. Department of Agriculture. Mr. Breazeale was directed in his work by Professor Whitney, Chief of the Bureau of Soils, and by the Director of this Station.

The work was carried on primarily in order to study the soluble toxic substances in a highly unproductive soil and also in soils in good tilth and of high productiveness. The influence of the treatment of the extracts of such soils with non-nutritive solid materials and with certain soluble chemical substances has been studied by way of water cultures with wheat both in the normal and treated extract. It has been fully recognized that one can not necessarily apply the conclusions drawn from water cultures to ordinary field practice, yet, by the study of water cultures of plants, valuable suggestions as to what occurs in the soil itself are often obtained. It is well known that the ordinary manurial substances contained in commercial fertilizers may sometimes injure soils, and they may also benefit them, even aside from their direct or indirect nutrient value upon the plants grown in them.

In earlier experiments at this Station a toxic effect upon plants was noticed after ammonium chlorid had been employed with acid phosphate and muriate of potash, but the toxic action disappeared when basic slag meal and potassium-magnesium carbonate were applied with the ammonium chlorid. A similar toxic effect was noticed also when ammonium sulfate was used with the same supplementary materials in the field and in pots, a condition which was overcome in the pots by the employment of either carbonate of lime or caustic magnesia. In the field lime only was employed, and then with full remedial effect. A single observation is also on record at this Station of a lack of toxic action when magnesium chlorid was added to a soil, while ammonium chlorid containing the same amount of chlorin was highly toxic. Possibly this latter action might not be repeated.

Many other illustrations of this double action of manurial substances could be cited from the field and pot experiments already conducted here. It is not surprising, therefore, that similar results should be obtained when working with water-extracts of soils.

The study of the influences of both soluble and solid substances upon these soil extracts is interesting and suggestive, and no one can predict its possible eventual bearing upon actual practice. To attempt to claim from the data obtained that because these manurial substances are beneficial to soil extracts in other ways than through their nutritive effects, where such a possibility of action exists, and that hence they do not play the role of plant nutrients in the soil when added, is not intended, nor is it to be inferred. Neither is it questioned but that the so-called chemical manures do in most instances, where they are applied to the "worn out" type of soils, exert a direct effect as nutrients upon the plants.

The action of the non-nutrient solids and of soluble bodies upon these extracts is not a source of surprise to those who understand the chemical and physical principles involved.

Owing to the lack of means, facilities, and assistants for undertaking such work at this time, the thanks of the Station are especially due to the Bureau of Soils for the aid rendered. It gives me great pleasure to acknowledge the valuable aid and suggestions made in connection with the work by Professor Whitney, Chief of the Bureau of Soils, also by Doctors Cameron and Livingston of the same Bureau. Thanks are likewise due Dr. B. L. Hartwell for assistance rendered to the authors in the course of the preparation of the manuscript of this article.

ON THE CAUSES OF UNPRODUCTIVITY IN A RHODE ISLAND SOIL.

Description of Soil.—The soil with which the present paper has to deal has been surveyed and mapped by F. E. Bonsteel and E. P. Carr. The following description is quoted from their report:*

"The soil of the Miami silt loam, to an average depth of 10 inches, is a brown silty loam containing a relatively small quantity of fine and very fine sand, which renders it mellow and friable. The surface compacts when wet, but does not bake on drying. The subsoil, to an average depth of 32 inches, is a uniform plastic yellow silt loam, becoming more sandy in the last few inches, and resting on a substratum of coarse sand and gravel below 32 inches. The whole type is free from stones and gravel except for a few glacial erratics and rounded bowlders scattered on the surface. Most of these have been picked off the fields and built into fences or crushed for road material.

"This type is found principally in the Kingston plain, where it presents a level surface, and near Peacedale, where it occurs as gently undulating hillocks and as a level table-land. Its range in elevation is slight, and the type as a whole is best described as level and unbroken.

"Underdrainage is generally good, from the coarse and porous nature of the materials underlying the subsoil at no great depth, but the surface is usually so level and the soil so compact that water stands on the surface after heavy rains and remains late in the spring after the melting of the snow. Areas sufficiently inclined to permit drainage, of course, do not suffer from standing water. The texture and structure of the soil and subsoil are such that they are capable of maintaining a sufficient moisture supply for the entire growing season; yet they are not so impervious as to impede the capillary movement of soil moisture, as do the heavy clays. The type therefore falls within the lighter class of desirable grass and grain producing soils, and is also adapted to a wide range of heavy truck and canning crops.

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*Bonsteel, F. E., and Carr, E. P., Soil Survey of Rhode Island. Field Operations, Bureau of Soils, U. S. Dept. Agriculture, 1905.

"The Miami silt loam is derived from reworked glacial material laid down as a sediment from quiet water under uniform conditions. These sediments form a superficial layer, rarely more than three feet in depth, over the coarser water-deposited materials of the plain. The predominance of silt in such a localized area in only one of the plains would point to the Miami stony loam, which occupies large surrounding areas, as the probable source of the materials. The pale color of the subsoil indicates the low state of oxidation of the iron salts, while the brown color and mellow texture of the soil indicate that it has been derived from the subsoil by direct weathering and the incorporation of organic remains."

The following table, taken from the same report, gives mechanical analyses of typical samples of this soil:

No.	LOCALITY.	DESCRIPTION.	Fine gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0 mm.
			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
11,700	1 mile S. E. of Kingston	Brown silty loam, 0 to 10 inches.	2.1	6.7	4.2	9.5	12.5	53.8	11.2
11,698	½ mile E. of Slocum..........	Brown silty loam, 0 to 11 inches.	0.6	1.9	1.1	2.2	13.4	64.9	15.3
11,699	Subsoil of 11,698.	Yellow silty loam, 11 to 36 inches.	0.7	1.6	0.5	1.2	8.3	82.9	4.7
11,701	Subsoil of 11,700.	Yellow silty loam, 10 to 36 inches.	1.5	5.4	2.9	6.6	13.7	62.6	7.3

Methods.—The soil extract for these experiments was prepared by the method described in Bulletin No. 23 of the Bureau of Soils. One part of soil by weight was stirred three minutes with two parts of distilled water, then allowed to stand 20 minutes and filtered under pressure through a clean Pasteur-Chamberland filter. Since distilled water as it is ordinarily prepared in chemical laboratories has been found to be markedly toxic to wheat plants grown in water culture, and since this toxicity is in a very large measure corrected by filtering the water through carbon black,* all of the water used in these experiments was so treated. Distilled water was shaken thoroughly with well-washed carbon black obtained from the burning of petroleum, and the solid was then filtered out by means of filter papers. By this method any deleterious substances originally in the water were first removed before the soil extract was prepared, thus avoiding any question which might arise in regard to the properties of the water employed. All soil extracts and solutions were thoroughly aerated, by shaking, before they were used in the cultures.

The cultures were grown in wide-mouth bottles of black glass, capacity about 60 cc., the seedlings being fixed in small openings in the margins of the flat cork stoppers in the manner described in the bulletin above cited. The plants were so placed that the seed was just above the surface of the solution, while the roots were almost entirely submerged. The Russian variety of wheat known as "Chul" was used in all of these cultures. The seeds were germinated in moist sand and were transferred to the culture bottles when the sprouts had attained a length of from two to four centimeters, care being taken in preparing the experiments to use seedlings as uniform in size and vigor as possible. The experiment lasted about two weeks, and the media were replaced at intervals of three to four days by new ones freshly prepared. Weighings of the cultures were made at intervals of two or three days and the several losses in weight, being a measure of the amount of water transpired, were added together for the total transpiration. In these weighings three bottles were grouped together and considered as a culture unit. The cultures were grown in a glasshouse, and were given as large an amount of sunshine as was allowed by the weather. Under these conditions the effect of the increase in weight of the plants upon the determinations of the water transpired was negligible, and no account was taken of it. Loss of water by evaporation from the bottles was reduced to a quantity so small as to be also negligible.

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* **Breazeale, J. F.** (1), Effect of solids upon the growth of wheat in water cultures, Bot. Gazette, 1905.

It has been shown by Livingston* that under conditions similar to those of the present experiments the amount of water lost by transpiration is a fair measure of the growth of wheat plants during the first few weeks after germination, and this criterion was used in this work. At the end of the experiment the tops of the plants were removed just above the juncture of root and stem, and their green weights determined, the latter being taken as a second criterion of growth. It was found in these experiments that the results were not always the same by each of these criteria. A third criterion often of aid is the apparent general condition of the plant.

Experiments and Results.—In the beginning of this work a large sample of Miami silt loam was taken from that section of the Experiment Station farm known as the "artificially exhausted soil." This soil includes plats Nos. 74, 76, 78, 80, 82, and 84. It has been under continuous culture without grass for ten years, is in very poor chemical and physical condition, and does not represent the usual normal condition of this class of soils in Rhode Island. Indian corn will not attain a height of over five and one-half inches in this soil during the entire season. It was selected for these experiments on account of its low productivity. In an aqueous extract of this soil wheat seedlings made a very poor growth. Furthermore, certain peculiarities of the roots which characterize seedlings grown in the soil itself are also exhibited to a marked degree by the cultures in the soil extract. The roots are short and thickened and fail to branch normally. Evidently the immediate cause of the unproductiveness of this soil is transmitted to a considerable extent to its extract. This seems to be generally true whenever a soil and its extract are compared in this way. From this it appears that in the majority of cases the mechanical condition of the soil is not the only immediate though possibly one of the primary causes of its failure to produce good crops, for a mechanical peculiarity of the soil can not be transmitted to an aqueous extract.

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* Livingston, B. E., Relation of transpiration to growth in wheat. Bot. Gazette, 40, 178–195 (1905).

The properties of a solution may be effective in retarding the development of plants growing therein in one or both of two general ways: First, the physical properties of the solution, such as viscosity, osmotic pressure, etc., may retard growth or even inhibit it, and this without regard to the chemical nature of the dissolved substances to which the solution owes its properties. Second, the chemical nature of the solution may retard growth, either through the presence of bodies which are injurious to plants, or through the absence of necessary salts.

In attempting to determine the nature of the properties of the extract of the infertile Miami silt loam which makes it injurious to wheat plants, both of these possible modes of action need to be considered. Of the various physical properties of solutions the only one which is likely to be effective in this case is that of osmotic pressure. That the osmotic pressure of a solution may be too low to give the best growth of plants is very probable, although little has been done in the way of quantitative experimentation in this regard. Convincing qualitative evidence in favor of this idea has been presented recently.* It has been shown that the growth of wheat in a dilute nutrient solution is markedly increased by the addition of a soluble salt such as sodium chlorid, when sufficient amounts of this salt for all possible food requirements of the plants were already present in the solution. This increased growth was apparently due to the higher osmotic pressure of the solution acting directly or indirectly upon the plants.

It has long been known that the osmotic pressure of a solution might be too high for growth owing to the tendency of strong solutions to withhold water from the plant. Quantitative data on this subject are still markedly lacking in the case of higher plants. This whole subject is thoroughly discussed and the experimental evidence brought together up to the time of writing by Livingston.*

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* **Breazeale, J. F.** (2), Effect of the concentration of the nutrient solution upon wheat cultures, Science, N. S. 22, 146–149 (1905).

Several valuable studies have been made on lower forms. It is a well-known fact that in nutrient solutions which are too concentrated for normal growth, plants are in general either killed outright or show a dwarfing very similar to that produced by lack of water.

That certain soils contain soluble substances which are injurious to plant growth, apparently through their chemical nature, has long been known.† That extracts of soils are frequently toxic to plants has also been pointed out recently in Bulletin No. 23 of the Bureau of Soils of the U. S. Department of Agriculture, and this matter is treated more thoroughly for one particular soil in Bulletin No. 28 of the same Bureau.

Some of the possible causes of the injurious properties of the extract of the infertile Miami silt loam at Kingston, R. I., will now be considered.

In the first place, the effect of adding to the soil extract the three main plant-food constituents, potassium, phosphorus, and nitrogen, was tested. The salts used were potassium sulfate, disodium phosphate, and sodium nitrate. These were tried separately and in combination. Experiment I deals with these tests. It continued from April 22 to May 6, 1905, and comprised thirty-six plants for each of the different treatments. Transpiration data were taken for the last eight days of the period, and the green weights of the plant tops were determined at the end of the test. The data for this experiment are given in table I. The figures immediately following the names of the salts denote parts per million of the particular food constituents which were added, it being assumed on the ground of much similar experimentation that the small amounts of sulfate and sodium ions necessarily accompanying the food constituents would have at most a negligible effect upon the plant. Following the columns giving the actual results are others which give the percentage gain brought about by the several treatments, these gains being calculated on the basis of the green weight and transpiration, respectively, of the cultures in untreated soil extract, considered as unity.

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* Livingston, B. E., The rôle of diffusion and osmotic pressure in plants; Part II, Chap. IV, Chicago, 1903.

† See especially DeCandolle, A. P., Physiologie Végétale, Paris, 1832.

TABLE I.

DATA FOR EXPERIMENT I.

Treatment of extract of the infertile Miami silt loam with plant-food constituents.

TREATMENT OF EXTRACT.	TRANSPIRATION.		GREEN WEIGHT OF TOPS.	
	Grams.	Per cent. gain.	Grams.	Per cent. gain.
Untreated	68.0	......	2.85	......
K_2SO_4 (K 50 p.p.m.)	129.4	90	5.55	95
$NaNO_3$ (NO_3 50 p.p.m.)	102.9	51	4.90	72
Na_2HPO_4 (PO_4 50 p.p.m.)	148.5	119	6.75	37
K_2SO_4 and $NaNO_3$ (K and NO_3 each 50 p.p.m.)	185.2	172	5.50	93
K_2SO_4 and Na_2HPO_4 (K and PO_4 each 50 p.p.m.)	135.8	100	4.35	52
$NaNO_3$ and Na_2HPO_4 (NO_3 and PO_4 each 50 p.p.m.)	172.8	154	5.20	82
K_2SO_4, $NaNO_3$ and Na_2HPO_4 (K,NO_3 and PO_4 each 50 p.p.m.)	242.2	256	4.25	49

From these results it appears that all of the treatments had a decidedly beneficial effect. This shows at once that the failure of the untreated extract to produce normal growth of wheat can not be considered as due to too high a concentration of dissolved substances, for the addition of these salts must have increased the concentration to a noticeable degree.

From the last paragraph it may be inferred that the concentration of this soil extract is too low to give normal growth of the culture plants. This is doubtless true, but the effect of the low concentration is apparently not the sole factor inhibiting growth. Experiment II, which was designed to throw light upon this point, is inconclusive. It was carried from May 5 to May 23, 1905, the transpiration being taken for the last eleven days. Thirty-six plants were used for each of the two treatments. The results are given in table II, which is arranged in the same manner as table I.

TABLE II.

DATA FOR EXPERIMENT II.

Comparison of rain water with extract of the infertile Miami silt loam.

TREATMENT.	TRANSPIRATION.		GREEN WEIGHT OF TOPS.	
	Grams.	Per cent. gain.	Grams.	Per cent. gain.
Soil extract prepared with filtered rain water.	67.7	....	3.1	....
Filtered rain water	73.5	9	3.1	0

While the transpiration of the plants grown in the rain water was somewhat higher than that of those grown in the soil extract, the difference is too small to draw any definite conclusions as to the relative gain of one over the other. It seems certain that the nutrient salts which were present in the soil extract were prevented in some way from exerting their due effect upon the plants.

Experiment III was another test of a similar nature, but in this case the soil extract was prepared with carbon-treated distilled water, and a portion was also diluted to twice its volume with the same water. This test was carried on with experiment I, the same number of seedlings being used for each treatment and the same culture in untreated extract being used as control. The result showed that the diluted extract produced an improvement in growth of seven per cent. by transpiration and 37 per cent. by green weight. These data support the idea mentioned above, yet further experimentation in the same line would be desirable.

Having shown that an important cause of the poor growth of wheat in this extract appears to lie in its chemical properties, there are two questions which at once arise: First, can the facts be explained upon the supposition that the solution is deficient in nutrient salts? And, second, may the poor growth in the untreated extract be due, not wholly to a lack of beneficial and necessary chemical materials, but to the presence of some injurious or toxic substances?

An examination of the results of experiment I would seem to indicate that the first supposition is true, and that the extract is deficient in plant-food salts, a view which is supported by the small amount of salts in the extract, viz., 68 parts per million. It is possible that when one more of these salts is added growth is increased mainly because there is a better supply of nutrient material for the plant to draw upon. However, if the other supposition were also true, the addition of non-injurious soluble salts to the extract might so alter the conditions in the solution or in the plant, or in both together, that the injurious substances assumed in this supposition might become non-injurious. In other words, injurious substances may be present which prevent the plants from growing normally, and at the same time they may be suffering to some extent from a lack of nutrient salts.

Additional light upon these questions is obtained by comparing the growth of plants in a nutrient solution prepared with distilled water with the growth in another nutrient solution prepared with exactly the same salts in the same proportions, but with soil extract substituted for pure water. In this case the second solution must necessarily possess a somewhat greater content of soluble material than the former, since *some* substances must dissolve from the soil and be present in the extract. Therefore, if the nutrient solution prepared with soil extract exhibits a markedly poor growth as compared with the other solution, it must be concluded that the retardation of growth is due to the presence of injurious bodies.

Such a test of the properties of this soil extract was made as experiment IV. The nutrient solution used contained 82 parts per million of calcium nitrate and 88 parts per million of dipotassium phosphate. The experiment was carried on simultaneously with experiment II, the same number of seedlings being used for each treatment. The data are given in table III. The percentage figures are calculated upon the basis of the normal nutrient solution, growth therein being considered as unity. It will be observed that they are negative in this case.

TABLE III.

DATA FOR EXPERIMENT IV.

Growth of wheat in nutrient solution prepared with pure water and with soil extract of the infertile Miami silt loam.

CULTURE MEDIUM.	TRANSPIRATION.		GREEN WEIGHT.	
	Grams.	Per cent. loss.	Grams.	Per cent loss.
Nutrient solution prepared with pure water..	120.5	....	4.2	....
Nutrient solution prepared with soil extract.	95.5	20.8	3.7	11.9

A marked deleterious effect was produced by the use of soil extract instead of pure water. There is, therefore, no logical alternative to the conclusion that the extract contains in solution substances which retard the growth of wheat in water culture. The nutrient solution was a dilute one, and the growth of the plants should have been improved by increasing its concentration. The optimum concentration for the growth of wheat* in a similar solution is about 300 parts per million of total salts, while the solutions employed contained only 170 parts per millon. An extract of this soil had a total salt content of about 68 parts per million, and thus the nutrient solution prepared from the extract should have contained in all not more than about 238 parts per million, a concentration which is seen to be far below the optimum for the growth of this plant. We must consider, then, that the injurious bodies of the soil exert their effect in retarding growth in spite of the slight increase in concentration produced by the presence of soluble salts in the extract. The possible presence of injurious substances is also suggested in the case of experiment II, and is shown as probable in experiment III already described; for the normal soil extract must have a slightly higher concentration than either distilled water or the diluted extract, and yet the plants remained in as good condition in water and made a slightly better growth in the diluted extract than in that which was undiluted.

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* Breazeale, J. F. (2), loc. cit.

Another method of attacking the problem as to whether the unproductiveness of this soil extract is partially or wholly due to the presence of deleterious substances is to determine whether a marked beneficial effect is produced by some treatment calculated to remove from the extract, or to destroy, any toxic substances that might be present, without at the same time adding any soluble bodies which might be of use to the plant as food material, or which might increase the concentration of the extract. In certain cases where toxic bodies have been shown to exist in soil extracts*, these bodies are removed or altered so as to become non-toxic by the introduction into the extract of practically insoluble or very slightly soluble solids in a finely divided condition. The solids which have so far been found to act in this way are precipitated ferric hydrate, carbon black, aluminum hydrate, quartz flour, and other substances which offer a large surface of contact with the extract. The first two of these and also recently formed limonite have been tested with this soil extract. Experiment V was the first in this connection. It was carried out at the same time and with the same number of plants as experiment I, and the same culture in untreated soil extract was used as control. Table IV presents the results. The amount of solid added to each 100 cc. of the extract is stated after the name of the solid. In this case and in those which are to follow only the percentage gains will be given, these being the only data which are of interest in these considerations.

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* See Breazeale, J. F. (1), loc. cit. See also Bul. No. 28 of the Bureau of Soils, U. S. Dept. Agr., On the influence of the presence of solids on the action of toxic substances in solution; see True, R. H., and Oglevee, C. S., The effect of the presence of insoluble substances on the toxic actions of poisons, Bot. Gaz., 39, 1–21 (1905); a preliminary statement of these results appeared in Science N. S., 19, 421–424 (1904). Also see Dandeno, J. B., The relation of mass action and physical affinity to toxicity, etc., Am. Jour. Sci., 17, 437, 458 (1904.)

TABLE IV.

DATA FOR EXPERIMENT V.

Effect of finely divided solids in extract of the infertile Miami silt loam.

TREATMENT OF EXTRACT.	PERCENTAGE GAIN.	
	By transpiration.	By green weight.
Ferric hydrate, 0.5 gram	159	68
Carbon black, 0.1 gram	104	61

A comparison of these results with table I shows that the percentage gains here recorded are as great as many of those obtained where only one or two of the nutrient salts were employed. Experiment VI, which was carried on in the same series as experiment II, showed that recently formed limonite had an effect similar to, though less striking, than that of precipitated ferric hydrate. It caused a gain of 58 per cent. by transpiration and 16 per cent. by green weight.

The ferric hydrate used in experiment V was prepared from ferric nitrate and ammonium hydrate, and was thoroughly washed to free it as far as possible from adhering ammonia and ammonium nitrate. It was not allowed to dry, but was kept in the condition of a thin paste, and was added to the soil extract in this form and was then well shaken so as to secure its uniform distribution. The carbon black was prepared by the burning of petroleum and was thoroughly and repeatedly washed in boiling water and then allowed to dry. It was added to the soil extract in the dry form, and was thoroughly distributed by stirring. Fresh solid material was used whenever the extracts were renewed. It appears impossible that the marked improvement which resulted from the addition of carbon black to the soil extract could have been due to any soluble materials which it carried into the solution, and the reason for its action appears to lie in its well-known absorptive power.

That the ferric hydrate used may have introduced into the solution small amounts of ammonia and of ammonium nitrate is possible. It has been found in the laboratories of the Bureau of Soils, however, that minute quantities of nitrates when added to a soil extract, or a dilute nutrient solution, produce but little appreciable beneficial effect; and the amount which was brought into solution in the extract by the ferric hydrate here used, after its thorough washing, must have been exceedingly small. Ammonia, prepared so as to remove any toxic metals possibly present, is still very toxic to wheat plants even in extremely dilute solutions, and no acceleration has been produced by its use in any concentration. Thus it is improbable that the beneficial effect of the ferric hydrate was due to either ammonium nitrate or to ammonia itself.

In order to reduce the last point to an absolute certainty, some ferric hydrate was prepared from ferric chlorid and sodium hydrate, thus avoiding altogether the possibility that ammonia or ammonium nitrate might be present in it. This was thoroughly washed and then divided into two portions, one of which was treated with ammonia and ammonium nitrate and then thoroughly washed again, while the other received no further treatment. Thus one of these portions of ferric hydrate should have been absolutely free from ammonia and ammonium nitrate, while the other may have contained a small amount of them in an absorbed state, so that washing with water failed to remove them. These two portions of ferric hydrate were subjected to tests in different portions of the same soil extract, to determine whether the solid which had been treated with ammonia and ammonium nitrate might be more or less effective than the other portion which probably contained small amounts of sodium hydrate and sodium chlorid.

This test will be termed experiment VII. The soil extract used was from soil of plat No. 17 of the Rhode Island Agricultural Experiment Station, which has been in grass for seven consecutive years and has received annually applications of phosphates and potassium salts, but no nitrates nor other nitrogenous manures. The cultures were carried on from July 28 to August 12, 1905, having 28 plants for each treatment.

TABLE V.

DATA FOR EXPERIMENT VII.

Effect of ferric hydrate with and without ammonia, in extract of a Miami silt loam. (*Plat No.* 17.)

TREATMENT OF EXTRACT FROM PLAT NO. 17.	PERCENTAGE GAIN.	
	By transpiration.	By green weight of tops.
Ammonia-free ferric hydrate	34.0	6.7
Ammonia-treated ferric hydrate	11.9	3.5

It is apparent at once that both lots of ferric hydrate produced some improvement in the growth of the plants, but that the effect of the ammonia-free material was more than double that of the other. This experiment shows that the beneficial effect of ferric hydrate as used in the other experiment was apparently not due to ammonia nor ammonium nitrate carried into the extract by the solid.

That a small amount of soluble iron is carried into the extract by ferric hydrate is probable, and it might be claimed that it would bring about the result which was observed; yet in other cultures to which iron was added in the metallic state, only a doubtful beneficial effect was produced, as in experiment VIII.

Ammonia-free ferric hydrate, ammonia-treated ferric hydrate, ferric hydrate prepared from ferric nitrate and ammonia, and metallic iron were included in this series. The extract used was made from the soil of the "infertile plats." The cultures were grown from

August 27 to September 9, 1905, 28 plants being used for each treatment. The results are given in table VI. Ferric hydrate, when indicated in the table, was shaken up with the soil extract and filtered out. The filtrate was then used for the cultures. The treatment with metallic iron consisted in adding about one-half of a gram of pure granular iron to each bottle and allowing this to remain during the growth of the plants.

TABLE VI.

DATA FOR EXPERIMENT VIII.

Effects of three preparations of ferric hydrate, when shaken with the soil extract and filtered out, and of metallic iron.

	PERCENTAGE VARIATION.	
	By transpiration.	By green weight of tops.
Amnonia-free ferric hydrate	182.9	0.0
Ammonia-treated ferric hydrate	67.2	3.1
Ferric hydrate made from nitrate and ammonia	139.9	4.7
Metallic iron (c. p.) added in small amount to extract	11.2	—2.0

This experiment agrees with experiment VII, as far as transpiration is concerned, in regard to the relative effects of the first two preparations of ferric hydrate. The variations in green weight are seen to be very slight in this case. The effect of metallic iron when present in the extract during the growth of the plants appears to be very small and doubtful in its direction, inasmuch as it was positive by transpiration and negative by green weight.

Since the ferric hydrate here used was not allowed to remain in contact with the soil extract during the growth of the plants, but was filtered out before the latter were placed in the extract, the increase in transpiration following this treatment must have been due to some action of the solid upon the soil extract rather than upon the roots themselves, or to its action upon substances which may have been excreted from the roots or produced by the action of other organisms during the growth of the wheat plants.

In addition to what has been said above regarding the effect of ferric hydrate, it is well known that practically all soils contain enough iron for plant growth; and it has been found by experiment in the laboratories of the Bureau of Soils that a slight increase in the amount of soluble iron in several different soil extracts failed to produce any marked improvement in the plants.

That carbon black exerts its effects here mainly upon the soil extract rather than upon the roots of the plants or upon substances possibly excreted from these organs, was shown by experiment IX. In this experiment, extending from September 14 to 29, 1905, 24 plants were used in each treatment and the transpiration data were taken for eight days. The results above show that when the carbon black was left in the extract it produced an increase of 177.5 per cent. by transpiration and 45 per cent. by green weight, while when the solid was filtered out before the cultures were prepared the increase was 217.7 per cent. by transpiration and 53.3 per cent. by green weight.

From the results given above it may be concluded as practically certain that ferric hydrate exerts its effect through its absorptive power, and it is probable that carbon black, which also accelerates growth, is effective in the same manner. This indicates that the effect of these solids is probably not to add any soluble material to the extract, but to remove some material from solution. And since this removal of some substance or substances from the extract produces a marked increase in the growth of wheat, we are brought finally to the conclusion that the extract used in these cultures contained injurious bodies which are removed or rendered non-injurious through the absorbent action of finely divided solids. It will be recalled that Voelcker* found a soil extract to be toxic, and

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* Jour. Roy. Agr. Soc. England, 64, 361 (1903).

Wheeler* *et al.* in 1895 suggested the possible presence of even non-acid toxic substances in soils.

It appears to be probable from evidence obtained in the laboratories of the Bureau of Soils† that there is considerable truth in the theory advanced by De Candolle in his Vegetable Physiology, and that wheat plants do excrete substances from their roots which are toxic to themselves. These substances seem to be more or less altered or removed from solution by the presence of either carbon black or ferric hydrate in the nutrient medium. From this fact it may be possible that some of the deleterious bodies which are met with in the culture tests in the extract of the infertile Miami silt loam were derived, at least in part, from the roots of the very plants used in the cultures. This is possible and to a certain extent probable even in those cases where the solid was not filtered out, owing to a lack of complete efficiency of the solid; but the conclusion that the soil extract at the outset contained deleterious substances and that these were partly removed or rendered much less toxic by the effect of the absorbing agents is rendered highly probable by the suggestions and facts brought out by experiments II, III, IV, VIII, and IX.

Another solid which, when used in the same way, is even more markedly beneficial than the solids just discussed, is calcium carbonate. It would hardly seem possible that the addition of this salt to the soil extract could produce a strikingly beneficial effect merely through the soluble calcium added. Calcium is one of the elements necessary to plant growth, but it is required by most plants in very small amounts, and wheat seedlings do not suffer appreciably from its absence in the nutrient medium during the first few weeks of their growth. In the case of extract of Takoma soil (see Bulletin No. 28, Bureau of Soils), it was found that calcium carbonate had a very marked beneficial effect just as it had here. In that case it was shown that this effect could not be related to calcium as a plant-food constituent, because calcium sulfate, although slightly beneficial, failed to show an effect parallel to that of the carbonate. The sulfate was tried in the present instance, but with this soil extract it had as marked an effect as the carbonate.* Experiment X included treatment of an extract of the infertile Miami silt loam with calcium carbonate by leaving the solid in contact with the solution during the growth of the plants and likewise by filtering it off before the plants were placed in the medium. It also included treatment with calcium sulfate, at the rate of 210 parts per million, and a triple treatment which consisted in shaking the extract with calcium carbonate, filtering out the excess, and then adding both ferric hydrate and carbon black, the latter solids remaining in the extract during the growth of the plants. This experiment was carried on simultaneously with experiment II, the same number of plants was employed and the same set of cultures in untreated extract was used as control. The results are given in table VII.

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* Eighth Ann. Rpt., R. I. Agr. Expt. Sta. (1895), p. 260; also Rpt. for 1900, p. 324.

† Breazeale, J. F. (1), loc. cit. Also Bulletin No. 28, Bureau of Soils, U. S. Dept. of Agr.

TABLE VII.

DATA FOR EXPERIMENT X.

Effect of calcium carbonate upon extract of infertile Miami silt loam.

TREATMENT.	PERCENTAGE GAIN.	
	By transpiration.	By green weight of tops.
Calcium carbonate in excess 0.5 per cent	139	23
Calcium carbonate, filtered out	106	16
Calcium sulfate, 210 p. p. m	134	39
Calcium carbonate, filtered out, ferric hydrate and carbon black, not filtered out	363	39

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* In pot and field trials at the R. I. Station, in soil located but a few feet distant from the soil employed in this instance, the action of calcium sulfate was found to be much inferior to that of calcium carbonate when the actual amounts of calcium oxid were identical. See Sixth Ann. Rpt., R. I. Agr. Expt. Station (1893), p. 257; also Eighth Ann. Rpt., R. I. Agr. Expt. Station (1895), p. 269. This shows that one can not necessarily conclude from water cultures what will result in the soil itself.—H. J. WHEELER.

It appears that when the carbonate is shaken with the extract and then filtered out it has a somewhat less marked effect than when it is left in contact, and that calcium sulfate has about the same effect as the carbonate when the latter is not filtered out. It also appears that after treating with calcium carbonate and filtering, the extract was further improved by the addition of ferric hydrate and carbon black. A test of the effect of ferric hydrate, carbon black, and calcium carbonate, all left in contact with the extract, constituted experiment XI, which was carried on in the same series as experiment I. The result showed a gain of 226 per cent. by transpiration and 81 per cent. by green weight. The effect of the carbonate may be partly due to its absorbent power as a finely divided solid, but the effect of the sulfate can not be explained in this manner, since the salt was added in solution. Therefore, since the latter salt is just as effective as the carbonate, it appears probable that soluble calcium, either as sulfate or carbonate is an active agent in correcting the toxicity of the soil extract. It is possible that the toxic substances of the extract are altered by the presence of these calcium salts in solution so as to become non-toxic.

Although, as has been noted above, it is improbable that the effect of the calcium salts is wholly due to their nutrient value, yet this point has not yet been established on an experimental basis. There is at least one other substance, however, which has a beneficial effect and which can not possibly be considered as a plant-food constituent. This is pyrogallol, which contains nothing but carbon, hydrogen and oxygen, and can therefore possess no nutrient value. As in the case of the extracts of Takoma soil (Bul. No. 28, Bureau of Soils, U. S. Dept. Agr.), small amounts of this phenol were found to have a marked beneficial effect upon the present extract. The test of this, experiment XII, was included in the same series with experiment II and comprised the same number of plants. The treatments and results are shown in table VIII. The phenol was added in solution so as to give several different concentrations in the extract. It was found in the case of the Takoma soil that large amounts of pyrogallol had an injurious effect, but that the injury was avoided without at the same time destroying the beneficial effect of the phenol by neutralizing it with trimethylamine. In the present experiment the phenol was added at the rate of 40 parts per million, and then enough trimethylamine was added to neutralize the acidity of the treated extract.

TABLE VIII.

DATA FOR EXPERIMENT XII.

Effect of pyrogallol upon extract of the infertile Miami silt loam.

TREATMENT OF EXTRACT.	PER CENT. VARIATION.	
	By transpiration.	By green weight of tops.
Pyrogallol 1 p. p. m.	10	0
Pyrogallol 5 p. p. m.	24	—6
Pyrogallol 10 p. p. m.	53	6
Pyrogallol 25 p. p. m.	93	3
Pyrogallol 40 p. p. m., neutralized	83	6

The figures show that pyrogallol was undoubtedly beneficial. The effect was quite marked, as shown by transpiration figures, but practically no differences were shown by the green weight of tops. In general appearance the plants showed the effect as markedly as do the transpiration figures.

Since the results here presented can not be explained on the ground that a nutrient substance had been added, and since the amount of pyrogallol added was not sufficient to alter the physical concentration of the soil extract to any appreciable degree, the logical conclusion seems to be that the toxic substances of the extract are so acted upon by the pyrogallol as to become less injurious. In this regard this soil is similar to Takoma lawn soil, though the effect of the phenol is less pronounced.

In connection with experiment I, attention was called to the fact that the transpiration and weight of plants grown in this soil extract were markedly increased by the addition of the nutrient salts. But since similar results to a greater or less extent can be obtained without the addition of nutrient material, as in experiments with pyrogallol, ferric hydrate, and carbon black,* it seems possible that in some cases the addition of these nutrient substances may have an effect aside from merely increasing the nutrient value of the solution. This view is strongly supported by the observation, made in experiment X, that calcium sulfate when added to the extract in the proportion of 210 parts per million produced such a marked gain in transpiration and green weight, and by a further observation that sodium chlorid in the proportion of 230 parts per million acted in the same way. The last observation was made in experiment XIII, which was included in the series with experiment II, having the same number of plants and the same control. Sodium chlorid, added to the soil extract in the proportion of 230 parts per million, produced a gain of 34 per cent. by transpiration and 13 per cent. by green weight. It will be noticed that this treatment was not as effective as the addition of the usual nutrient salts nor as the addition of calcium sulfate. It is possible that sodium chlorid failed to show as great an increase as the other salts because of the toxic and therefore retarding effect of the chlorin ion. The toxic action of certain chlorids in pot experiments in the absence of basic compounds has been shown by the Rhode Island Agricultural Experiment Station, but in the presence of basic substances no apparent toxic action was observed.

The question regarding the effect of concentration of the nutrient solution on the growth of plants is discussed in a paper already cited,† and the suggestion is there made that the effect of higher concentration in improving the growth of the plants is probably due to some alteration thus produced in the relation between the plant and the toxic substance excreted by its roots. It is stated that:

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* Whether the calcium sulfate and calcium carbonate, which were highly beneficial, are to be regarded as nutrients or otherwise in this connection is still an open question.

† Breazeale, J. F., loc. cit. (2).

"The effect of increase in concentration may be explained by one or more of the three following hypotheses: The higher concentration may make the plant more resistant to the poisons; it may actually prevent the excretion of such poisons from the roots; or with higher concentration of salts the poisons themselves may be altered so as to lose their toxic properties."

In the case of these soil extract experiments where the solution is changed frequently, a beneficial effect due to an increase in concentration by the addition of salts is hardly possible, excepting through the first and last of the three means suggested. The higher concentration may cause the plant to become more resistant to the toxic bodies of the extract, or these bodies themselves may be altered so as to become non-toxic. It is at present impossible to decide finally between these possibilities.

Two experiments were carried out in order to make possible a comparative study of the effects produced in the extract of the infertile soil by carbon black, ferric hydrate, the manurial salts, and sodium chlorid. Experiment XIV dealt with ferric hydrate and comprised 24 plants. It continued from September 8 to September 23, 1905, the transpiration being for the last nine days of the period. The treatments and results are given in table IX. In Nos. 3 and 4 the solid and soluble salts were both present throughout the growth of the plants. The total salt content in No. 1 was 254 p. p. m.; therefore the total percentage of salts was the same in all three treatments in which they were employed. This was also true of all the following experiments.

TABLE IX.

DATA FOR EXPERIMENT XIV.

Relative effects of ferric hydrate, manurial salts, and sodium chlorid in extract of the infertile Miami silt loam.

Number.	Treatment of Extract.	Percentage Gain.	
		By transpiration.	By green weight.
1	NO_3, K, PO_4, each 50 p.p.m., in $NaNO_3$, K_2SO_4 and Na_2HPO_4	317.6	137.5
2	Ferric hydrate, not filtered out	247.6	114.0
3	Treatment of (2) and (1)	323.4	129.1
4	Treatment of (2) + NaCl 254 p.p.m	230.6	50.2

It is seen from the table that all of the treatments had a very marked beneficial effect. The effect of the manurial salts, with or without the solid, was considerably greater than that of the solid (ferric hydrate), while the effect of sodium chlorid with the solid was less than that of either the manurial salts or the ferric hydrate when used alone. It thus seems clear that the effect of the solid was not diminished by the presence of manurial salts, but that this effect was diminished by the presence of sodium chlorid. This strengthens still further the suggestion made above, that the latter salt had an injurious effect in the extract.

Experiment XV dealt with carbon black, and comprised 24 plants for each treatment. It extended from September 14 to September 29, 1905, the transpiration data being taken during the last eight days. The treatments and results are shown in table X.

TABLE X.

DATA FOR EXPERIMENT XV.

Relative effects of carbon black, manurial salts, and sodium chlorid in extract of the infertile Miami silt loam.

Number.	TREATMENT OF EXTRACT.	PERCENTAGE GAIN.	
		By transpiration.	By green weight.
1	NO_3, K and PO_4, each 50p. p. m., in $NaNO_3$, K_2SO_4 and Na_2HPO_4	458.3	194.4
2	Carbon black, filtered out	217.7	53.3
3	Treatment of (2) and (1)	563.4	191.7
4	Treatment of (2) + NaCl 254 p. p. m	164.8	61.5
5	Carbon black, not filtered out	177.5	45.0
6	Treatment of (5) and (1)	537.9	240.7
7	Treatment of (5) + NaCl 254 p. p. m	215.2	74.2

This experiment agreed with the last in that both manurial salts and carbon black had a marked beneficial effect, and also in that the beneficial effect of the manurial salts was greater than that of the solid, this being true whether the latter was filtered out or not. When either method of carbon treatment was used in connection with the manurial salts the combined effect was greater than that of either when used alone. This single experiment indicated that the additional carbon treatment somewhat improved the effect produced by the manurial salts alone, which was not observed in the preceding experiment with ferric hydrate. When the solid was filtered out, the addition of sodium chlorid to the treated extract produced no marked additional increase in growth, although the two criteria, transpiration and green weight, are not in accord on this point. When the carbon black was not filtered out, the addition of the last-named salts produced a definite improvement. It appears possible, therefore, that a part of the effect produced by the manurial salts may have been due to an increase in the concentration of the soil extract, that sodium chlorid had a smaller effect in the same way, and that carbon black had an effect in some manner different from and practically independent of the other two treatments.

To compare the results of the last two experiments upon the infertile soil with the effects produced upon good soils, the three following experiments were performed: Experiments XVI and XVII were similar to experiment XV, and dealt with ferric hydrate and carbon black, respectively, in an extract of soil from plat 29 of the Rhode Island Agricultural Experiment Station. This plat has been treated annually with but few exceptions for a period of twelve years with approximately 800 pounds of dissolved bone-black; 300 pounds muriate of potash; 465 pounds sodium nitrate; and, for a lesser period of time, 400 pounds sulfate of magnesia per acre. Three applications of lime were made during the entire period. The plat was in legumes at the time the sample was taken, and the growth of certain varieties of these plants showed the soil to be in good condition, while other varieties showed the reverse to be true. At all events this soil stands in marked contrast to the infertile soil with which the preceding experiments (excepting experiment VII) have had to deal, for, as is stated on page 292, that soil was in an exceedingly poor condition, as shown by the last crop grown upon it.

Experiment XVI comprised 24 plants for each treatment. It was continued from September 24 to October 9, 1905, the transpiration measurements being made during the last ten days. The results are presented in table XI.

TABLE XI.

DATA FOR EXPERIMENT XVI.

Relative effects of ferric hydrate, manurial salts, and sodium chlorid in extracts of soil from Plat 29, Rhode Island Agricultural Experiment Station.

Number.	TREATMENT OF EXTRACT.	PERCENTAGE VARIATION.	
		By transpiration.	By green weight.
1	NO_3, K and PO_4, 50 p. p. m. each, in $NaNO_3$, K_2SO_4, Na_2HPO_4	172.7	95.7
2	Ferric hydrate, filtered out	91.1	2.4
3	Treatment of (2) and (1)	214.7	112.0
4	Treatment of (2) + NaCl 254 p. p. m.	96.5	13.7
5	Ferric hydrate, not filtered out	85.3	—2.8
6	Treatment of (5) and (1)	207.4	103.8
7	Treatment of (5) + NaCl 254 p. p. m.	135.5	16.6

Experiment XVII comprised 24 plants for each treatment, and was continued from October 2 to October 16, 1905, transpiration being determined for the last five days. The results are given in table XII.

TABLE XII.

DATA FOR EXPERIMENT XVII.

Relative effects of carbon black, manurial salts, and sodium chlorid in extract of soil from Plat 29, Rhode Island Agricultural Experiment Station.

Number.	TREATMENT OF EXTRACT.	PERCENTAGE VARIATION.	
		By transpiration.	By green weight.
1	NO_3, K and PO_4, 50 p. p. m. each, in $NaNO_3$, K_2SO_4 and Na_2HPO_4	117.9	88.1
2	Carbon black, filtered out	17.2	—10.3
3	Treatment of (2) and (1)	110.0	77.8
4	Treatment of (2) + NaCl 254 p. p. m.	55.8	24.2
5	Carbon black, not filtered out	20.8	—31.4
6	Treatment of (5) and (1)	76.6	73.1
7	Treatment of (5) + NaCl 254 p. p. m.	20.2	5.5

In these experiments the effect of the manurial salts when used alone was much less than in the case of the poor soil, as should be expected from general field experience, for this soil has a comparatively high productive power, and is probably not capable of very marked improvement for most varieties of plants. The effects of ferric hydrate and carbon black were far less beneficial than in the case of the infertile soil. They were both helpful in this instance, as concerns the transpiration, but these effects become practically negligible, in view of the accompanying losses in green weight, in three of the four instances. The effect of the manurial treatment was benefited to some extent by treatment with ferric hydrate, yet these differences were too small to be strongly conclusive. Its effect was diminished by a similar additional treatment with carbon black. When the sodium chlorid treatment followed that with ferric hydrate where the latter was removed by filtering, the combined effect was a little greater than with the solid alone, and this condition was much more decided when the chlorid was added to the extract with the ferric hydrate remaining in contact. When the extract was shaken with carbon black and the solid filtered out, and then sodium chlorid added, the chlorid seemed to be beneficial; but its effect was slightly injurious, as indicated by the transpiration, when carbon black was allowed to remain in the extract. It should be borne in mind, however, that many of the differences were too small to have any particular significance.

Experiment XVIII was similar to experiments XVI and XVII, but was carried out with an extract of soil from plat 11 of the Rhode Island Agricultural Experiment Station. This is one of the plats in rotation "C." The rotation used is winter rye, clover, and potatoes, each one year. During the season of 1905 this plat was in potatoes. The manurial treatment in the earlier years of the rotation is described in Bulletin No. 74 (1900). In the later years only minor changes have been made. The soil is in good agricultural condition, as shown by the recent crops taken from it. The present experiment comprised 24 plants for each treatment, and continued from October 2 to October 17, 1905, transpiration being determined for the last five days. The results are given in table XIII.

TABLE XIII.

DATA FOR EXPERIMENT XVIII.

Relative effects of carbon black, ferric hydrate, manurial salts, and sodium chlorid in extract of soil from Plat 11, *Rhode Island Agricultural Experiment Station.*

Number.	TREATMENT OF EXTRACT.	PERCENTAGE GAIN	
		By transpiration.	By green weight.
1	NO_3, K and PO_4, 50 p.p.m. each, in $NaNO_3$, K_2SO_4 and Na_2HPO_4	139.7	99.1
2	Carbon black, filtered out	45.9	9.2
3	Treatment of (2) and (1)	167.0	113.0
4	Treatment of (2) + NaCl, 254 p.p.m.	63.9	9.7
5	Carbon black, not filtered out	106.1	0
6	Treatment of (5) and (1)	150.1	80.5
7	Treatment of (5) + NaCl, 254 p.p.m	64.9	19.4
8	Ferric hydrate, filtered out	51.5	8.4
9	Treatment of (8) and (1)	177.3	115.2
10	Treatment of (8) + NaCl, 254 p.p.m	60.8	15.1
11	Ferric hydrate, not filtered out	42.8	1.7
12	Treatment of (11) and (1)	153.6	128.7
13	Treatment of (11) + NaCl, 254 p.p.m	47.4	23.2

This soil resembles that of plat 29, giving only comparatively slight increases with manurial salts, with ferric hydrate or with carbon black, as compared with the first one employed. As was noted in the case of the soil of plat 29, this failure is probably related to the fact that this soil already has a relatively high productive power and can not be improved by any treatment. As before, the manurial salts gave a much greater increase in green weight and transpiration than the two solids. The combination of ferric hydrate or of carbon black with the manurial salts, excepting the green weight in No. 6, gave a greater increase than was produced by either treatment alone. The addition of sodium chlorid to the extract which had already been treated with ferric hydrate or carbon black produced a very slight increase above what would have been obtained without the chlorid; indeed a negative effect on the transpiration was produced by the chlorid in No. 7, which was treated with carbon black not filtered out.

From the results obtained in experiments XIV to XVIII, the most obvious, and likewise the most important, conclusion to be drawn is that in the case of the extracts of the infertile soil the manurial treatment and the treatments with ferric hydrate and carbon black were much more beneficial than the same treatments in the case of the good soils of plats 29 and 11. These experiments also show clearly that the effect of the manurial salts was much greater on the extracts of both poor and good soils than the effects produced by treatment of the extracts with the absorbing solids, ferric hydrate and carbon black.

The beneficial effects derived from the solids in experiments XIV to XVIII were always increased by the further treatment of the extract with manurial salts. The effect of the manurial treatment is shown to have been increased somewhat by ferric hydrate, whether the solid was filtered out or not, even in the case of the extracts of the two good soils. In the case of the poor soil the only test bearing upon this point is that of experiment XIV, in which the solid was left in the extract. In that test the criterion of transpiration showed the effect of the manurial salts to be increased by the solid, while the criterion of green weights showed the opposite. Therefore, the test is inconclusive. In the case of the poor soil the effect of the manurial salts was increased by further treatment of the extract with carbon black when the solid was not filtered out. When this solid was filtered out the evidence from the two criteria, transpiration and green weight, is discordant. A consideration of the large positive effect exhibited by the former criterion and of the small negative effect exhibited by the latter can merely be said to be suggestive in the same line. With the extract of the good soil from plat 29 the carbon treatment diminished the effect of the manurial salts. In the extract of soil from plat 11 the effect of the manurial salts was increased by carbon black when filtered off, but when the solid was left in the extract there was again a discrepancy between the two criteria, transpiration showing an increase and green weight a decrease.

Summarizing the points brought out in the last paragraph: The injurious effects of the solids were overcome in all cases and the beneficial effects of the solids were increased in other instances by the addition of manurial salts. The effect produced by the manurial salts was slightly improved by ferric hydrate in the case of the two good soils, conclusive data being lacking for the poor soil. The effect of the manurial salts was probably improved by carbon black as shown by transpiration and green weight, except for a lesser green weight in one of the two trials, in the case of the poor soil. This effect was diminished by carbon black in the case of the soil from plat 29, and was by no means shown to be positively increased in that of the soil from plat 11.

It has been pointed out in earlier paragraphs that the soil extracts were often apparently benefited (1) by increasing their physical concentration, though in some instances injury resulted; (2) by increasing the amount of manurial salts; and (3) by removing or altering the toxic bodies which appear to be present in them. The beneficial effect of carbon black and ferric hydrate appears to have been due probably to the removal or alteration of toxic bodies. The beneficial effect of the manurial salts may be brought about in all three of the ways mentioned, though no positive evidence of the latter action has been brought forward. Addition of these salts assuredly increases the concentration (and that without the addition of a toxic body like sodium chlorid), increases the supply of mineral nutrient materials, and may possibly bring about chemical changes in the toxic bodies of the extract, resulting in their becoming less toxic. To separate the well-established nutrient value of a salt from this suggested sanitary value, which appears to exist, and to show positively the actual existence and extent of the latter, must require very extensive and painstaking work. The present contribution can not be said to have done more than to have barely touched upon this problem.

The fact that in some cases treatment of the soil extract with an absorbing solid followed by the addition of the manurial salts gave a greater increase in the growth of the plants than was obtained with the soluble salts alone shows quite clearly that the functions of these two classes of substances are different, or that insufficient amounts of each were used. As has been said above, the manurial salts may have been effective in increasing the concentration of the extract and in furnishing a larger supply of nutrient materials. The absorbing solids can not be effective in this way, and their effect is probably to be attributed to a removal or alteration of the toxic bodies of the extract.

Regarding the effect of sodium chlorid in these experiments, when this salt was added to the soil extract which had already been treated with a solid with or without its subsequent removal, the result in the case of the poor soil was in one instance to decrease both transpiration and green weight, in another to lower the transpiration and to raise the green weight, and in another to raise both. Excepting the transpiration in two instances in the case of the better soils (plats 11 and 29), the results pointed to slight or decided benefit from the sodium chlorid.

As has been suggested previously, the effect of sodium chlorid is probably brought about by two antagonistic sets of factors, the beneficial effect of increase in physical concentration and of possible action upon toxic bodies, and the injurious effect of the increase in the concentration of the chlorin ions. If this be true it is not difficult to explain the apparent difference between the effect of this salt in solid-treated extracts of the poor soil and of the good soils. In the extract of the poor soil more toxic principles are still acting which retard the growth of plants. In the extract of the good soils the injurious factors are not nearly so active, and after treatment with the solids they are perhaps practically removed. Thus in the latter extract, owing to the presence of a lesser amount of toxic substances, the plants might not show injury upon the addition of chlorids, especially in view of the previous liming of both of these soils, while the beneficial tendency of the increase in physical concentration which accompanies the addition of the chlorid should be equally potent in both extracts. The problem regarding the effect of sodium chlorid in soil extract or nutrient solutions is still further complicated by the possibility that some part of the beneficial effect often derived from its use is due to direct benefit to the plant itself, as suggested by certain unpublished experiments by the authors, and also by the bare possibility that it has a favorable chemical effect upon certain toxic bodies of the soil itself, in a manner similar to that suggested above as possible for certain manurial salts. Thus the problem here is seen to be an exceedingly complex one which will require a great deal of careful experimentation before a complete solution of it may be hoped for.

SUMMARY.

In the present paper it is shown that the unproductiveness of the infertile Miami silt loam from the farm of the Rhode Island Agricultural Experiment Station, at Kingston, R. I., is in some measure transmitted to the aqueous extract of this soil. The physiological properties of this extract have been investigated in several particulars.

There are at least four different ways in which it is possible for a soil extract to retard growth: First, it may have too high a physical concentration; second, it may have too low a concentration; third, it may not contain a sufficient supply of plant-food constituents; and fourth, it may contain substances which are injurious to plants. The first of these possibilities concerning this particular soil extract is at once ruled out of consideration, because the addition of salts to this extract increased plant growth therein. The second possibility might in a measure be considered as ruled out by the fact that the diluted extract gave at least as good growth as was obtained in the normal extract; yet it is quite possible that the benefit arising from a dilution of toxic substances present in the extract might be sufficient to fully offset the tendency to lessen growth by diluting the nutrient materials. Treatment of the extract with finely divided carbon black and ferric hydrate must seemingly be effective through the absorbing power of these solids, and the beneficial effect of this treatment must probably be regarded as due to the removal of some substances from the extract. This seems to indicate that the extract contained injurious bodies which were removed from or altered in the soil extract so as to become non-injurious, or partially so, by the action of the solids above named. Some evidence in the same direction is derived from the fact that treatment of the extract with pyrogallol produced a gain in transpiration in all cases and in green weight in three of the five instances. This phenol can not be considered as a nutrient material, so that the conclusion is suggested that certain toxic substances present in the extract are acted on chemically by the pyrogallol and brought into a less injurious form. It is suggested that the beneficial action of calcium carbonate and calcium sulfate in these experiments may be in part of a similar nature.

The soil extracts were unquestionably improved for the growth of wheat plants by the addition of considerable amounts of sodium nitrate, potassium sulfate, sodium acid phosphate, and in certain cases by sodium chlorid. The beneficial effects brought about by these salts may, *a priori*, be due to one or more of four possible modes of action: (1) They increase the physical concentration of the extract, and this may make the plants less susceptible to the injurious action of the toxic bodies. (2) They may act chemically upon the plants, and by furnishing them with nutrient or stimulating materials may thus enable them to better withstand the action of the toxins. (3) Some or all of the salts may act chemically upon the toxic substances themselves, in the manner suggested for pyrogallol and the calcium salts. (4) They unquestionably do act as plant nutrients, excepting possibly sodium chlorid under certain conditions. The evidence seems to point to the idea that one or more of the first three of these modes of action may sometimes be important, aside from or in conjunction with the fourth; but the problem of analyzing the general effect into its particular components and relating each component to its cause is one which lies far beyond the reach of the present researches. The question as to just how the salts acted in all particulars must be left an open one for the present.

A comparison of the effects produced by the various treatments of the extract of the infertile soil with those produced by the same treatments upon extracts of two soils of the same farm which were in good condition for the growth of crops shows that none of the treatments produced nearly as good effects upon the extract of the good soil as upon that of the poor soil; yet treatment with carbon black and ferric hydrate in a few cases seemed to produce a small beneficial effect upon the extracts of the good soils, and these bodies were probably effective through the removal of injurious substances from the extract. Therefore it may be supposed that the toxic bodies which apparently exist in relatively large amounts in the extracts of the infertile soil may be present also to a slight extent in that of the good ones.

The soluble toxic bodies of the infertile soil seem in some respects to be similar in their effect to those which have been shown to exist in the Takoma soil, as described in Bulletin No. 28 of the Bureau of Soils. The extracts differ mainly in the degree and character of the effect which nutrient salts, calcium sulfate, and pyrogallol exert upon plants growing therein.

DIVISION OF ANIMAL HUSBANDRY.

In the absence of a report from this Division, readers are referred to the report of the Director, pages 179 to 183, for a brief statement of what has been done during the year.

REPORT OF METEOROLOGIST.

NATHANIEL HELME.

Some changes have taken place in this division during the past year. In view of the fact that a station of the U. S. Weather Bureau with an official forecaster in charge was located in Providence in October, 1904, the special predictions which for a little more than fourteen years have been sent from here to the Evening Bulletin, were discontinued at that time, and at the end of the year the monthly summaries which had been published in that paper were discontinued for the same reason. In March, 1905, a letter from the Weather Bureau Station in Boston stated that, owing to the limited appropriation for telegraph service, the weather forecasts which had been sent from there daily, and had been displayed here by means of flag signals from the belfry of Library Hall in Kingston village, would have to be discontinued, but if the public wished it, it might be resumed after July 1st.

Summary for 1904–1905.

Highest temperature................	87°	July 19, 1904.
Lowest temperature................	—4°	February 4, 1905.
Range for the year.................	91°	
Highest monthly mean..............	68.3°	July, 1904.
Lowest monthly mean..............	21°	February, 1905.
Highest daily mean.................	75°	July 19 and 20, 1904.
Lowest daily mean.................	7.5°	February 4, 1905.
Mean temperature of the year.......	45.3°	

Precipitation (rain and melted snow).

Greatest in any 24 consecutive hours	2.48 inches, August 10, 1904.
Greatest total for one month.......	7.63 inches, August, 1904.
Smallest total for one month.......	1.69 inches, May, 1905.
Total for the year.................	41.64 inches.
Total snowfall (unmelted)..........	51.00 inches.

Prevailing Winds.

Southwest: July, August, September, 1904; May, June, 1905; West: October, November, December, 1904; January, February, March, April, 1905.

Weather.

Number of clear days in the year	151
Partly cloudy days	122
Cloudy days	92
Days with .01 inch or more of precipitation	99

Summary by Months for 1904–1905.

MONTHS.	Highest temperature.	Lowest temperature.	Mean temperature.	Precipitation (rain and melted snow), inches.	Snowfall (unmelted).	Clear days.	Partly cloudy days.	Cloudy days.	Days with .01 inch or more of precipitation.	Prevailing wind direction.
1904.										
July	87°	48°	68.3°	2.47	......	10	13	8	9	S.W.
August	83°	45°	66.3°	7.63	......	12	10	9	8	S.W.
September	82°	29°	60.6°	1.97	......	12	12	6	10	S.W.
October	78°	20°	48.2°	2.30	......	16	8	7	4	W.
November	57°	7°	35.4°	3.15	1¾	15	12	3	5	W.
December	50°	4°	23.1°	4.97	28	7	15	9	11	W.
1905.										
January	49°	—1°	28.9°	4.37	13	14	10	7	11	W.
February	45°	—4°	21.0°	2.18	8¾	15	5	8	5	W.
March	68°	8°	34.7°	2.86	......	13	9	9	10	W.
April	70°	23°	44.5°	2.83	......	11	12	7	8	W.
May	80°	30°	55.0°	1.69	......	14	8	9	9	S.W.
June	85°	38°	62.8°	5.22	......	12	8	10	9	S.W.
Total	......	......	......	41.64	51½	151	122	92	99	......
Mean	69.5°	20.6°	45.3°	......	......	......	......	......	......	......

The principal characteristics of the weather for each month were as follows:

The July mean temperature was 1° below the average for the month. There were no extremely high temperatures, but the large percentage of humidity made the weather uncomfortable at times. The rainfall was one inch less than the mean for the month for 16 years.

The mean temperature of August was nearly 2° below the average for the month for 16 years. During the first two decades of the month the rainfalls were frequent and heavy, making the total for the month three and one-half inches above the average and the largest for August on our record.

The September mean temperature was below, and the rainfall one-half, the average for the month for 17 years. The minimum temperatnre of 29° was the lowest for September on our record.

October was a month of fine autumnal weather, with an abundance of sunshine. The mean temperature was below the average, and the lowest for the month since 1895. The rainfall was less than one-half the average for 17 years.

The November mean temperature was below the average, and it was the coldest November on our record. There was a flurry of snow on the 6th, and the first snow of sufficient depth to measure fell on the 27th. The precipitation was below the average.

The mean temperature of December was 7° below the average, making it the coldest on our record. This was owing to the low maxima rather than to any extremely low temperatures, as at no time did it register zero or below as has been the case in December in previous years. The ground was covered with snow for the greater part of the month, and there were several days of good sleighing.

The January precipitation and temperature were each below the average for the month, and at the end of the month there was no snow on the ground.

It was the coldest February on our record. There was snow on the ground throughout the month, and the total precipitation was less than one-half the average. The mean temperature of the three winter months of 1904–1905 was 22.7° and for the same time in 1903–1904 it was 22.6°, making but a slight difference between the two.

March was notable for absence of the high winds which generally prevail in that month. The precipitation was less than one-half the average, while the mean temperature was about the normal.

The April mean temperature was but slightly below the average. At the close of the month vegetation was not very far advanced, it having been hindered by the cold nights and not very warm days.

May was quite a dry month, the rainfall being less than one-half the average for the month. There was a killing frost on the 2nd, and light frost on low land on the 21st and 22nd. The temperature was about the normal for the month.

The June temperature was below, and the rainfall above, the average for the month. There was frost on low land on the morning of the 9th.

The following tables give the temperature, rainfall, wind direction and character of the day for each day of the year, and a general summary for the years from January 1, 1890, to June 30, 1905, inclusive:

WEATHER SUMMARY FOR JULY, 1904.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	73°	63°	68.°	.81	S.	Cloudy.
2	74	55	64.5	.04	S.W.	Clear.
3	72	48	60.	....	N.W.	Clear
4	73	49	61.	....	S.W.	Clear.
5	77	61	69.	.05	S.	Fair.
6	78	62	70.	.15	S.	Cloudy.
7	77	61	69.	.07	S.	Cloudy.
8	77	58	67.5	....	S.E.	Fair.
9	76	53	64.5	....	E.	Clear.
10	77	59	68.	....	Variable.	Fair.
11	81	60	70.5	....	S.W.	Cloudy.
12	77	65	71.	....	S.W.	Fair.
13	80	61	70.5	trace.	N.W.	Fair.
14	80	49	64.5	....	N.W.	Clear.
15	80	57	68.5	....	Variable.	Fair.
16	82	62	72.	....	S.	Fair.
17	83	62	72.5	....	S.W.	Clear.
18	85	61	73.	....	S.	Fair.
19	87	63	75.	....	Variable.	Clear.
20	85	65	75.	....	W.	Clear.
21	82	58	70.	....	W.	Clear.
22	75	60	67.5	.16	E.	Cloudy.
23	63	57	60.	.87	N.E.	Cloudy.
24	66	56	61.	.26	N.	Cloudy.
25	75	60	67.5	....	S.W.	Fair.
26	80	61	70.5	....	S.W.	Fair.
27	79	65	72.	.06	S.W.	Fair.
28	80	62	71.	....	S.W.	Cloudy.
29	80	62	71.	trace.	W.	Fair.
30	75	52	63.5	....	W.	Clear.
31	80	59	69.5	....	S.W.	Fair.
Sum......	2,049	1,826	2,117.5	2.47	....	....
Mean.....	77.7	58.9	68.3	....	....	....

Maximum temperature............87°.
Minimum temperature............48°.
Mean temperature.............68.3°.
Prevailing wind...........southwest.

WEATHER SUMMARY FOR AUGUST, 1904.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	82°	67°	74.5°	....	S.W.	Cloudy.
2	78	63	70.5	.68	S.W.	Cloudy.
3	80	60	70.	.57	Variable.	Fair.
4	72	60	66.	....	E.	Cloudy.
5	70	61	65.5	....	S.E.	Cloudy.
6	77	65	71.	.97	S.	Fair.
7	83	62	72.5	....	S.W.	Clear.
8	73	62	67.5	....	W.	Fair.
9	72	52	62.	....	Variable.	Clear.
10	69	52	60.5	2.48	E.	Cloudy.
11	82	65	73.5	....	S.W.	Fair.
12	71	55	63.	....	Variable.	Fair.
13	70	53	61.5	....	Variable.	Cloudy.
14	73	59	66.	.19	S.E.	Cloudy.
15	82	56	69.	....	N.W.	Clear.
16	75	59	67.	.16	E.	Cloudy.
17	82	62	72.	....	S.W.	Fair.
18	77	58	67.5	....	N.W	Clear.
19	75	49	62.	....	S.W.	Fair.
20	68	56	62.	2.05	S.	Cloudy.
21	81	62	71.5	....	N.W.	Clear.
22	78	57	67.5	....	S.W.	Clear.
23	75	54	64.5	....	Variable.	Clear.
24	77	49	63.	....	N.W.	Clear.
25	77	57	67.	....	S.W.	Clear.
26	74	54	64.	trace.	W.	Fair.
27	72	45	58.5	....	S.W.	Clear.
28	74	58	66.	....	S.W.	Fair.
29	82	55	68.5	....	W.	Fair.
30	69	55	62.	....	E.	Clear.
31	74	51	62.5	....	Variable.	Clear.
Sum......	2,344	1,763	2,058.5	7.63	....	....
Mean.....	75.6	56.9	66.3	....	....	....

Maximum temperature...........83°.
Minimum temperature...........45°.
Mean temperature.............66.3°.
Prevailing wind...........southwest.

WEATHER SUMMARY FOR SEPTEMBER, 1904.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	70°	50°	60.°	....	S.E.	Fair.
2	80	54	67.	....	S.W.	Clear.
3	81	62	71.5	....	S.W.	Clear.
4	82	60	71.	....	W.	Clear.
5	73	51	62.	....	W.	Fair.
6	67	47	57.	....	Variable.	Clear.
7	70	47	58.5	....	S.W.	Clear.
8	78	49	63.5	.03	S.W.	Fair.
9	59	55	57.	.04	N. E.	Cloudy.
10	70	51	60.5	....	S.	Clear.
11	73	52	62.5	.01	N. E.	Fair.
12	79	63	71.	.06	S.W.	Fair.
13	68	55	61.5	....	E.	Cloudy.
14	70	54	62.	.48	S.	Cloudy.
15	68	47	57.5	.85	N.W.	Fair.
16	67	42	54.5	....	S.W.	Clear.
17	75	51	63.	....	S.W.	Clear.
18	77	56	66.5	....	S.	Clear.
19	77	57	67.	....	Variable.	Fair.
20	70	53	61.5	.07	E.	Cloudy.
21	62	41	51.5	....	N.W.	Clear.
22	54	29	41.5	....	N.	Clear.
23	60	31	45.5	....	W.	Clear.
24	67	44	55.5	....	S.	Cloudy.
25	79	59	69.	.11	S.W.	Fair.
26	70	51	60.5	.02	Variable.	Fair.
27	69	51	60.	....	Variable.	Fair.
28	65	48	56.5	....	S.E.	Fair.
29	67	45	56.	.30	S.	Cloudy.
30	77	55	66.	....	W.	Fair.
Sum......	2,124	1,510	1,817	1.97	....	....
Mean.....	70.8	50.3	60.6	....	....	....

Maximum temperature............82°.
Minimum temperature............29°.
Mean temperature.............60.6°.
Prevailing wind...........southwest.

WEATHER SUMMARY FOR OCTOBER, 1904.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	62°	44°	53°	....	W.	Fair.
2	57	39	48.	....	W.	Fair.
3	62	36	49.	....	W.	Clear.
4	63	35	49.	....	W.	Clear.
5	64	41	52.5	....	S.	Fair.
6	57	37	47.	trace.	N.W.	Fair.
7	52	29	40.5	....	Variable.	Clear.
8	60	32	46.	....	S.	Fair.
9	64	51	57.5	.04	S.W.	Cloudy.
10	65	49	57.	....	S.	Cloudy.
11	75	50	62.5	....	Variable.	Fair.
12	50	40	45.	1.35	N.E.	Cloudy.
13	47	36	41.5	....	N.W.	Cloudy.
14	62	32	47.	....	N.W.	Clear.
15	58	36	47.	....	N.W.	Clear.
16	65	29	47.	....	Variable.	Clear.
17	73	35	54.	....	S.W.	Clear.
18	78	44	61.	....	S.W.	Clear.
19	58	44	51.	....	N.E.	Cloudy.
20	67	49	58.	....	S.	Cloudy.
21	62	46	54.	.72	S.E.	Fair.
22	63	40	51.5	....	S.W.	Clear.
23	58	34	46.	....	S.W.	Clear.
24	53	31	42.	....	W.	Clear.
25	60	34	47.	....	S.W.	Fair.
26	58	41	49.5	.19	W.	Cloudy.
27	48	29	38.5	....	N.W.	Clear.
28	47	23	35.	....	S.E.	Clear.
29	58	35	46.5	....	W.	Clear.
30	47	27	37.	....	N.	Clear.
31	46	20	33.	....	N.W.	Clear.
Sum......	1,839	1,148	1,493.5	2.30	....	....
Mean.....	59.3	37.	48.2	....	....	....

Maximum temperature...........	78°.	Mean temperature..............	48.2°.
Minimum temperature............	20°.	Prevailing wind................	west.

WEATHER SUMMARY FOR NOVEMBER, 1904.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	54°	29°	41.5°	....	N.W.	Fair.
2	50	28	39.	....	S.E.	Clear.
3	55	38	46.5	....	S.	Fair.
4	57	38	47.5	....	N.E.	Clear.
5	40	27	33.5	....	N.E.	Fair.
6	44	27	35.5	....	W.	Fair.
7	40	26	33.	....	W.	Clear.
8	47	22	34.5	....	W.	Clear.
9	33	29	31.	.42	N.	Fair.
10	48	26	37.	....	W.	Clear.
11	38	26	32.	.06	W.	Fair.
12	48	22	35.	....	S.W.	Clear.
13	44	28	36.	2.10	N.E.	Rainy.
14	42	30	36.	....	N.W.	Fair.
15	49	26	37.5	....	W.	Clear.
16	50	32	41.	....	W.	Fair.
17	34	18	26.	....	W.	Clear.
18	35	12	23.5	....	N.	Clear.
19	53	15	34.	....	W.	Clear.
20	55	33	44.	....	W.	Clear.
21	50	31	40.5	....	W.	Clear.
22	50	21	35.5	....	S.W.	Clear.
23	50	32	41.	....	W.	Fair.
24	46	33	39.5	....	N.W.	Cloudy.
25	42	26	34.	....	N.W.	Fair.
26	41	22	31.5	....	W.	Clear.
27	33	15	24.	.15	N.W.	Fair.
28	29	11	20.	....	N.W.	Clear.
29	49	7	28.	.42	S.	Cloudy.
30	50	36	43.	....	S.W.	Fair.
Sum......	1,356	766	1,061	3.15	....	....
Mean.....	45.2	25.5	35.4	....	....	....

Maximum temperature...........57°.
Minimum temperature............ 7°.

Mean temperature.............35.4°.
Prevailing wind................west.

WEATHER SUMMARY FOR DECEMBER, 1904.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	38°	22°	30°	trace.	W.	Clear.
2	31	20	25.5	....	W.	Fair.
3	26	19	22.5	....	N.E.	Fair.
4	26	12	19.	....	W.	Fair.
5	32	13	22.5	.40	Variable.	Cloudy.
6	34	16	25.	....	W.	Clear.
7	37	15	26.	....	W.	Fair.
8	31	18	24.5	....	W.	Fair.
9	24	11	17.5	....	W.	Clear.
10	14	5	9.5	.12	N.	Cloudy.
11	20	4	12.	....	W.	Clear.
12	28	7	17.5	.60	N.E.	Cloudy.
13	27	16	21.5	.40	N.	Fair.
14	19	5	12.	....	W.	Clear.
15	26	8	17.	trace.	N.	Fair.
16	32	15	23.5	.30	N.W.	Fair.
17	32	8	20.	....	S.W.	Fair.
18	32	18	25.	.80	N.W.	Fair.
19	40	12	26.	....	S.W.	Cloudy.
20	36	17	26.5	trace.	S.W.	Fair.
21	29	11	20.	....	W.	Clear.
22	29	4	16.5	....	S.W.	Fair.
23	43	29	36.	.05	S.W.	Cloudy.
24	41	18	29.5	trace.	N.W.	Cloudy.
25	22	9	15.5	.10	N.E.	Cloudy.
26	26	14	20.	....	N.E.	Cloudy.
27	47	25	36.	1.65	S.W.	Rainy.
28	50	24	37.	.50	S.W.	Fair.
29	32	18	25.	....	W.	Clear.
30	32	21	26.5	.05	W.	Fair.
31	46	20	33.	....	W.	Fair.
Sum......	982	454	718	4.97	....	....
Mean.....	31.6	14.6	23.1	....	....	....

Maximum temperature............50°. Mean temperature..............23.1°.
Minimum temperature............ 4°. Prevailing wind...............west.

WEATHER SUMMARY FOR JANUARY, 1905.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	49°	32°	40.5°	....	W.	Clear.
2	45	30	37.5	.10	S.W.	Fair.
3	39	19	29.	.42	N.E.	Rainy.
4	19	3	11.	.40	W.	Fair.
5	22	—1	10.5	....	W.	Clear.
6	34	6	20.	.30	N.E.	Cloudy.
7	48	32	40.	1.31	S.W.	Fair.
8	33	24	28.5	....	W.	Clear.
9	35	16	25.5	....	W.	Clear.
10	37	20	28.5	....	S.W.	Fair.
11	32	17	24.5	....	N.W.	Cloudy.
12	46	26	36.	.92	Variable.	Rainy.
13	37	19	28.	....	W.	Cloudy.
14	22	8	15.	....	N.W.	Fair.
15	22	2	12.	....	W.	Clear.
16	29	12	20.5	....	S.W.	Fair.
17	36	15	25.5	....	W.	Clear.
18	38	18	28.	....	W.	Clear.
19	45	23	34.	....	S.W.	Clear.
20	41	26	33.5	....	W.	Clear.
21	39	18	28.5	.04	E.	Cloudy.
22	39	27	33.	.27	W.	Fair.
23	32	10	21.	....	N.W.	Clear.
24	24	7	15.5	.05	N.E.	Fair.
25	24	5	14.5	.55	N.E.	Cloudy.
26	14	3	8.5	....	N.W.	Clear.
27	31	5	18.	....	W.	Clear.
28	33	14	23.5	.01	S.W.	Fair.
29	29	7	18.	....	W.	Clear.
30	22	11	16.5	....	N.	Fair.
31	25	7	16.	....	W.	Clear.
Sum......	1,021	461	741	4.37	....	....
Mean.....	32.9	14.9	23.9	....	....	....

Maximum temperature...........49°.	Mean temperature.............23.9°.
Minimum temperature...........—1°.	Prevailing wind ....west.

WEATHER SUMMARY FOR FEBRUARY, 1905.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	27°	5°	16.°	....	N.W.	Fair.
2	22	8	15.	....	N.W.	Clear.
3	18	1	9.5	....	N.W.	Clear.
4	19	—4	7.5	....	W.	Clear.
5	29	1	15.	....	S.E.	Fair.
6	33	19	26.	.72	N.E.	Cloudy.
7	28	13	20.5	....	W.	Clear.
8	32	7	19.5	....	N.E.	Clear.
9	32	17	24.5	.53	N.E.	Rainy.
10	38	23	30.5	....	Variable.	Cloudy.
11	27	12	19.5	....	W.	Clear.
12	34	5	19.5	.76	E.	Cloudy.
13	40	12	26.	.05	W.	Cloudy.
14	19	1	10.	....	W.	Clear.
15	26	5	15.5	....	Variable.	Cloudy.
16	19	2	10.5	....	W.	Clear.
17	37	11	24.	....	S.W.	Fair.
18	26	10	18.	....	W.	Clear.
19	22	4	13.	....	W.	Clear.
20	33	15	24.	.12	S.W.	Cloudy.
21	45	29	37.	....	Variable.	Clear.
22	32	19	25.5	....	N.E.	Cloudy.
23	32	17	24.5	....	N.	Clear.
24	40	19	29.5	....	N.W.	Fair.
25	40	18	29.	....	W.	Clear.
26	37	22	29.5	....	S.W.	Fair.
27	29	16	22.5	....	W.	Clear.
28	38	15	26.5	....	W.	Clear.
Sum.....	864	322	588	2.18	....	....
Mean.....	30.5	11.5	21	....	....	....

Maximum temperature...........45°.
Minimum temperature...........—4°.
Mean temperature...........21°.
Prevailing wind...........west.

WEATHER SUMMARY FOR MARCH, 1905.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	Max.	Min.	Mean.			
1	32°	17°	24.5°	....	W.	Clear.
2	30	18	24.	....	W.	Clear.
3	36	11	23.5	....	W.	Clear.
4	42	20	31.	....	W.	Fair.
5	28	9	18.5	....	S.W.	Fair.
6	36	18	27.	....	N.W.	Clear.
7	37	17	27.	.22	Variable.	Cloudy.
8	37	30	33.5	.57	S.	Rainy.
9	43	29	36.	.12	Variable.	Rainy.
10	48	30	39.	.36	W.	Fair.
11	35	20	27.5	....	W.	Clear.
12	38	20	29.	....	W.	Fair.
13	37	17	27.	....	W.	Clear.
14	38	18	28.	....	Variable.	Cloudy.
15	38	16	27.	....	W.	Clear.
16	47	21	34.	....	S.W.	Fair.
17	44	25	34.5	....	Variable.	Clear.
18	57	28	42.5	....	S.W.	Clear.
19	48	42	45.	.21	S.W.	Rainy.
20	42	30	36.	.02	N.	Cloudy.
21	33	29	31.	1.06	N.E.	Rainy.
22	37	25	31.	....	N.	Fair.
23	42	23	32.5	....	E.	Clear.
24	43	26	34.5	....	S.E.	Cloudy.
25	48	39	43.5	.21	S.W.	Cloudy.
26	60	36	48.	....	W.	Clear.
27	58	37	47.5	.01	W.	Fair.
28	68	37	52.5	....	W.	Fair.
29	60	40	50.	....	N.E.	Clear.
30	56	36	46.	.05	S.	Fair.
31	67	34	50.5	....	W.	Clear.
Sum......	1,365	788	1,026.5	2.86	....	....
Mean.....	44	25.4	34.7	....	....	....

Maximum temperature...	68°.	Mean temperature.............	34.7°.
Minimum temperature............	8°.	Prevailing wind...................	west.

WEATHER SUMMARY FOR APRIL, 1905.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	53°	35°	44.°	....	N.W.	Fair.
2	47	24	35.5	....	N.W.	Clear.
3	58	23	40.5	....	N.W.	Clear.
4	47	35	41.	.01	N.E.	Cloudy.
5	50	39	44.5	.44	N.W.	Cloudy.
6	50	36	43.	1.21	S.	Fair.
7	52	27	39.5	....	W.	Clear.
8	50	28	39.	....	W.	Fair.
9	56	26	41.	....	W.	Fair.
10	58	37	47.5	trace.	W.	Fair.
11	54	36	45.	.61	N.E.	Cloudy.
12	56	38	47.	....	N.E.	Fair.
13	49	36	42.5	....	N.E.	Cloudy.
14	60	36	48.	....	S.	Clear.
15	56	33	44.5	.10	N.W.	Clear.
16	50	32	41.	....	W.	Fair.
17	44	24	34.	....	W.	Clear.
18	50	30	40.	....	W.	Fair.
19	51	26	38.5	....	S.W.	Clear.
20	60	35	47.5	.17	S.	Fair.
21	60	42	51.	.27	S.W.	Cloudy.
22	53	36	44.5	....	Variable.	Clear.
23	57	31	44.	....	W.	Clear.
24	55	32	43.5	....	S.W.	Fair.
25	63	41	52.	....	W.	Clear.
26	65	41	53.	....	S.W.	Cloudy.
27	63	46	54.5	.02	Variable.	Fair.
28	59	38	48.5	....	N.E.	Fair.
29	57	36	46.5	....	S.	Cloudy.
30	70	41	55.5	....	W.	Clear.
Sum......	1,653	1,020	1,336.5	2.83	....	....
Mean.....	55.1	34	44.5	....	....	....

Maximum temperature...........70°.
Minimum temperature............23°.

Mean temperature................44.5°.
Prevailing wind..................west.

WEATHER SUMMARY FOR MAY, 1905.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	55°	36°	45.5°	....	W.	Clear.
2	58	30	44.	....	S.W.	Clear.
3	69	41	55.	....	S.W.	Clear.
4	56	42	50.	....	Variable.	Fair.
5	58	36	47.	....	S.E.	Fair.
6	66	43	54.5	....	S.W.	Cloudy.
7	79	50	64.5	.06	S.W.	Fair.
8	67	43	55.	....	Variable.	Clear.
9	66	40	53.	.15	N.W.	Fair.
10	70	42	56.	....	N.W.	Fair.
11	72	45	58.5	....	S.W.	Clear.
12	63	48	55.5	.53	S.W.	Cloudy.
13	60	45	52.5	....	E.	Cloudy.
14	59	45	52.	.62	Variable.	Cloudy.
15	73	51	62.	....	S.E.	Cloudy.
16	53	43	48.	.07	N.E.	Cloudy.
17	49	42	45.5	....	N.E.	Cloudy.
18	65	42	53.5	.08	S.W.	Fair.
19	68	47	57.5	....	W.	Clear.
20	56	46	51.	....	W.	Clear.
21	63	37	50.	....	S.W.	Clear.
22	70	39	54.5	....	S.W	Clear.
23	63	47	55.	.03	N.	Cloudy.
24	65	38	51.5	....	S.W.	Clear.
25	66	44	55.	....	S.W.	Clear.
26	72	52	62.	....	S.W.	Clear.
27	69	55	62.	.04	S.W.	Cloudy.
28	80	58	69.		S.W.	Clear.
29	79	54	66.5	....	W.	Fair.
30	67	50	58.5	.11	N.E.	Fair.
31	69	48	58.5	....	E.	Clear.
Sum......	2,027	1,379	1,703	1.69	....	....
Mean.....	65.4	44.5	55.	....	....	....

Maximum temperature...........80°.	Mean temperature...............55°.
Minimum temperature............30°.	Prevailing wind...........southwest.

WEATHER SUMMARY FOR JUNE 1905.

	Temperature.			Precipitation.	Prevailing wind.	Character of day.
	Max.	Min.	Mean.			
1	64°	47°	55.5°	....	N.E.	Fair.
2	72	42	57.	.03	S.W.	Fair.
3	72	49	50.5	....	W.	Clear.
4	74	44	59.	....	S.W.	Fair.
5	79	54	66.5	....	S.W.	Cloudy.
6	72	49	60.5	1.04	N.E.	Cloudy.
7	56	45	50.5	.05	N.E.	Cloudy.
8	54	44	49.	.22	N.	Fair.
9	72	38	55.	....	Variable.	Clear.
10	79	49	64.	....	S.W.	Clear.
11	69	51	60.	....	S.W.	Cloudy.
12	62	56	59.	2.15	S.W.	Cloudy.
13	74	56	65.	.34	S.W.	Cloudy.
14	81	59	70.	....	S.W.	Clear.
15	85	60	72.5	....	S.W.	Clear.
16	82	56	69.	....	S.W.	Clear.
17	77	57	67.	....	S.W.	Clear.
18	83	61	72.	....	S.W.	Fair.
19	68	51	59.5	.52	N.E.	Cloudy.
20	58	49	53.5	....	N.E.	Cloudy.
21	65	53	59.	.74	E.	Cloudy.
22	78	57	67.5	.13	W.	Fair.
23	81	63	72.	....	Variable.	Cloudy.
24	77	59	68.	....	S.W.	Fair.
25	80	53	66.5	....	S.W.	Clear.
26	82	56	69.	....	S.W.	Fair.
27	71	51	61.	....	N.W.	Clear.
28	74	47	60.5	....	N.W.	Clear.
29	80	53	66.5	....	W.	Clear.
30	82	55	68.5	....	S.W.	Clear.
Sum......	2,203	1,564	1,883.5	5.22	....	....
Mean.....	73.4	52.1	62.8	....	....	....

Maximum temperature............	85°.	Mean temperature...............	62°.
Minimum temperature............	38°.	Prevailing wind...........	southwest.

SUMMARY JANUARY 1, 1890, TO JUNE 30, 1905. INCLUSIVE.

	Maximum temperature.	Minimum temperature.	Mean temperature.	Number of clear days.	Partly cloudy days.	Cloudy days.	Days with .01 inch or more of precipitation.	Total precipitation, inches.
1890	91°	3°	48.3°	99	143	123	120	59.25
1891	94	5	49.4	116	154	95	83	49.88
1892	92	—1	47.8	147	116	103	89	42.58
1893	92	—6	46.5	126	130	109	131	57.33
1894	93	—9	48.6	110	130	125	114	48.19
1895	95	—7	48.2	128	114	123	108	49.28
1896	93	—11	47.7	131	112	123	109	49.87
1897	90	—1	48.3	129	126	110	128	54.25
1898	95	—4	48.8	110	114	141	131	72.21
1899, January 1 to June 30	95	—10	42.1	77	44	60	59	26.79
July 1, 1899, to June 30, 1900	90	—5	48.3	141	113	111	102	51.67
July 1, 1900, to June 30, 1901	97	—9	48.4	134	97	134	114	48.47
July 1, 1901, to June 30, 1902	93	—1	48.0	138	116	111	109	53.14
July 1, 1902, to June 30, 1903	90	—12	48.3	138	96	131	103	59.27
July 1, 1903, to June 30, 1904	93	—16	45.7	156	107	103	118	50.06
July 1, 1904, to June 30, 1905	87	—4	45.3	151	122	92	99	41.64

Average temperature for 15½ years........................46.4°.
Average precipitation for 15½ years..................52.51 inches.

REPORT OF THE TREASURER.

THE RHODE ISLAND AGRICULTURAL EXPERIMENT STATION, *in account with the* UNITED STATES APPROPRIATION, 1904–1905.

1905.	DR.		
	To receipts from the treasurer of the United States as per appropriation for fiscal year ended June 30, 1905, as per act of Congress approved March 2, 1887		$15,000 00

1905.	CR.		
	By Salaries	$9,377 76	
	Labor	1,854 43	
	Publications	45 67	
	Postage and stationery	144 76	
	Freight and express	109 40	
	Heat, light, water, and power	373 36	
	Chemical supplies	53 66	
	Seeds, plants, and sundry supplies	287 72	
	Fertilizers	169 03	
	Feeding-stuffs	645 80	
	Library	362 33	
	Tools, implements, and machinery	192 50	
	Furniture and fixtures	25 86	
	Live stock	432 50	
	Traveling expenses	268 39	
	Contingent expenses	15 00	
	Buildings and repairs	641 83	
			$15,000 00

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the Rhode Island Agricultural Experiment Station for the fiscal year ended June 30, 1905; that we have found the same well kept and classified as above, and that the receipts for the year from the treasurer of the United States are shown to have been $15,000, and the corresponding disbursements $15,000, for all of which proper vouchers are on file, and have been examined by us and found correct, thus leaving no balance.

And we further certify that the expenditures have been solely for the purposes set forth in the act of Congress approved March 2, 1887.

CHARLES DEAN KIMBALL,
C. H. COGGESHALL,
Auditors.

MELVILLE BULL, *Treasurer, in account with the* RHODE ISLAND AGRICULTURAL EXPERIMENT STATION, *for the year ended June* 30, 1905.

1905.	DR.	
	To Balance from last year	$2,611 31
	Station receipts	1,028 81
	Interest	98 33
		$3,738 45

1905.	CR.	
	By Labor	$318 17
	Publications	3 08
	Postage and stationery	7 62
	Chemical supplies	14 53
	Seeds, plants, and sundry supplies	25 92
	Fertilizers	4 50
	Feeding-stuffs	46 65
	Library	3 60
	Tools, implements, and machinery	37 66
	Furniture and fixtures	1 10
	Scientific apparatus	1 50
	Traveling expenses	25 35
	Contingent expenses	13 15
	Buildings and repairs	18 71
	Balance	3,216 91
		$3,738 45

This certifies that we, the undersigned, auditing committee of the Board of Managers of the Rhode Island College of Agriculture and Mechanic Arts, have examined the accounts of Melville Bull, treasurer of the Rhode Island Agricultural Experiment Station, and find the same correct.

The total receipts were $3,738.45, and the total expenditures were $621.54, thus leaving a balance to new account of $3,216.91.

CHARLES DEAN KIMBALL,
C. H. COGGESHALL.

Auditors.

EXCHANGES.

Aboriculture, Connersville, Ind.
Agricultural Advertising, Pittsburg, Pa.
Agricultural Epitomist, Spencer, Ind.
Agricultural Gazette of New South Wales, Australia.
Agricultural Ledger, Calcutta, India.
American Cultivator, Boston, Mass.
American Fancier, Johnstown, N. Y.
American Fertilizer, Philadelphia, Pa.
American Hay, Flour, and Feed Journal, New York.
American Horse Breeder, Boston, New York, and Chicago.
American Nut Journal, Petersburg, Va.
American Philosophical Society, Proceedings of the Society.
American Poultry Advocate, Syracuse, N. Y.
American Poultry Journal, Chicago, Ill.
American Sheep Breeder and Wool Grower, Chicago, Ill.
American Stock Farm, The, Winona, Minn.
American Stock Keeper, Boston, Mass.
American Sugar Industry and Beet Sugar Gazette, Chicago, Ill.
Breeders' Gazette, Chicago, Ill.
Bulletins of the Botanical Department of Jamaica, and Reports of Public Gardens and Plantations.
Bulletins of the New York State Museum.
California Cultivator, Los Angeles, Cal.
Chicago Daily Drovers' Journal, Chicago, Ill.
Colman's Rural World, St. Louis, Mo.
Connecticut Farmer, New Haven, Conn.
Corbett's Herald, Providence, R. I.

Current Numbers of Minnesota Botanical Studies, University of Minnesota.
Elgin Dairy Report, Elgin, Ill.
Evening Telegram, Providence, R. I.
Farm and Fireside, Springfield, Ohio.
Farm and Live Stock Journal, Detroit, Mich.
Farm, Field, and Fireside, Chicago, Ill.
Farm Home, The, Springfield, Ill.
Farm Journal, Philadelphia, Pa.
Farm Life, Chicago, Ill.
Farm Poultry, Boston, Mass.
Farm, Stock, and Home, Minneapolis, Minn.
Farmers' Advocate, London, Ontario.
Farmers' Guide, Huntington, Ind.
Farmers' Review, The, Chicago, Ill.
Farmers' Sentinel, Milwaukee, Wis.
Farmers' Tribune, Des Moines, Iowa.
Feather, The, Washington, D. C.
Feathered World, The, London, England.
Flour and Feed, Waukegan, Ill.
Fruit Grower, The, St. Joseph, Mo.
Geflugel-Buchter, Hamburg, Wis.
Hoard's Dairyman, Fort Atkinson, Wis.
Holstein-Fresian Register, Brattleboro, Vt.
Homestead, The, Des Moines, Iowa.
Hope Valley Free Press, Hope Valley, R. I.
Hospodarske Listy, Chicago, Ill.
Indiana Farmer, Indianapolis, Ind.
Inland Poultry Journal, Indianapolis, Ind.
Journal Royal Horticultural Society, London, England.
Kansas Farmer, Topeka, Kansas.
Kimball's Dairy Farm, Waterloo, Iowa.
Maryland Agricultural Quarterly, College Park, Md.
Massachusetts Ploughman, Boston, Mass.

Metropolitan and Rural Home, The, New York City.
Miscellaneous Publications, Department of Agriculture and Mines, Natal, Africa.
Modern Farmer and Busy Bee, The, St. Joseph, Mo.
Missouri Agricultural College Farmer, Columbia, Mo.
National Stockman and Farmer, Pittsburg, Pa.
Nebraska Farmer, Omaha, Neb.
New England Farmer, Brattleboro, Vt.
New England Homestead, Springfield, Mass.
New Farm, Preston, Md.
New Hampshire Farmer and Weekly Union, Manchester, N. H.
Northwest Horticulturist, Tacoma and Seattle, Wash.
Nut Grower, The, Poulan, Ga.
Ohio Farmer, Cleveland, Ohio.
Oregon Agriculturist, Portland, Oregon.
Orff's Farm and Poultry Review, St. Louis, Mo.
Poultry, Peotone, Ill.
Poultry Gazette, Kansas City, Kansas.
Poultry Herald, St. Paul, Minn.
Poultry Item, Fricks, Pa.
Poultry Standard, Stamford, Conn.
Poultry Success, Des Moines, Iowa.
Poultry Topics, Lincoln, Neb.
Practical Farmer, The, Philadelphia, Pa.
Practical Fruit Grower, Springfield, Mo.
Prairie Farmer, The, Chicago, Ill.
Providence News, The, Providence, R. I.
Publications of the Florida Department of Agriculture.
Publications of the Department of Argiculture, Mysore State, India.
Publications of the Imperial Agricultural Experiment Station, Nishigahara, Tokyo, Japan.
Publications of the Maine State Board of Agriculture.
Publications of the Massachusetts State Board of Agriculture.
Publications of the Department of Agriculture, New Zealand.

Publications of the North Carolina State Board of Agriculture.
Publications of the Department of Agriculture, University College, North Wales.
Publications of the Ohio State Board of Agriculture.
Publications of the Pennsylvania Department of Agriculture.
Publications of the Rhode Island State Board of Agriculture.
Publications of the Department of Agriculture, Victoria.
Publications of the Virginia Department of Agriculture.
Publications of the Department of Agriculture of Western Australia.
Queensland Agricultural Journal, Australia.
Reliable Poultry Journal, Quincy, Ill.
Republic, The, St. Louis, Mo.
Rock Products, Louisville, Ky.
Rural New-Yorker, New York City.
Rural World, London, England.
Skandinavisk Farmer Journal, Minneapolis, Minn.
Southern Fancier, Atlanta, Ga.
Southern Planter, Richmond, Va.
Successful Farming, Des Moines, Iowa.
Successful Poultry Journal, Chicago, Ill.
Sugar Beet, The, Philadelphia, Pa.
Sec. da Agr. Estado de São Paulo, Boletim da Agriculture.
Texas Farmer, Dallas, Texas.
Transvaal Agricultural Journal, India.
Up-to-Date Farming and Gardening, Indianapolis, Ind.
Wallace's Farmer, Des Moines, Iowa.
Western Fruit Grower, St. Joseph, Mo.
W. Weedel & Co.'s Colonial Dairy Produce Report, London, England.
West Virginia Farm Review, Charleston, W. Va.
Wilson Bulletins, Wilson Ornithological Club, Oberlin, Ohio.
Wisconsin Agriculturist, Racine, Wis.
Yearbook and Current Publications der Deutschen Landwirtschafts-Gesellschaft.

Directions for Binding the Bulletins and Reports of the Rhode Island Experiment Station.

Vol.	1–3*,	Bulletins	1–9,	Reports,	1–3,	1888–1890.
"	4,	"	10–14,	Report,	4,	1891.
"	5,	"	15–20,	"	5,	1892.
"	6,	"	21–26,	"	6,	1893.
"	7,	"	27–30,	"	7,	1894.
"	8,	"	31–35,	"	8,	1895.
"	9,	"	36–42,	"	9,	1896.
"	10,	"	43–46,	"	10,	1897.
"	11,	"	47–51,	"	11,	1898.
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* Vols. 1–3 in one cover. Beginning with volume 4, a title page and index for each volume is to be found at the end of the annual report for each year. The year covered by a volume formerly was the calendar year, but now it extends from July 1 to June 30. Each volume, beginning with volume 4, is paged separately. The Bulletins of a given year precede the Report, and the latter is paged in continuation of the last Bulletin belonging in the volume.

BULLETINS

AND

ANNUAL REPORT

OF THE

RHODE ISLAND AGRICULTURAL EXPERIMENT STATION,

FOR THE

YEAR ENDING JUNE 30,

1905.

PROVIDENCE:
E. L. FREEMAN & SONS, STATE PRINTERS
1906.

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OF THE

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OF THE

RHODE ISLAND AGRICULTURAL EXPERIMENT STATION,

FOR THE

YEAR ENDING JUNE 30, 1905.

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State of Rhode Island and Providence Plantations.

NINETEENTH ANNUAL REPORT

OF THE

RHODE ISLAND AGRICULTURAL EXPERIMENT STATION, Kingston

1905-1906.

PART II.

OF THE

NINETEENTH ANNUAL REPORT

OF THE

CORPORATION, BOARD OF MANAGERS

OF THE

Rhode Island College of Agriculture and Mechanic Arts,

MADE TO THE

GENERAL ASSEMBLY AT ITS JANUARY SESSION, 1907.

[PARTS I. AND III. OF THIS REPORT — REPORT OF PRESIDENT AND BOARD OF MANAGERS AND COLLEGE CATALOGUE — ARE PRINTED UNDER SEPARATE COVERS.]

PROVIDENCE, R. I.:
E. L. FREEMAN COMPANY, PRINTERS TO THE STATE.
1907.

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OF THE

RHODE ISLAND

College of Agriculture and Mechanic Arts.

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BURT L. HARTWELL, Ph. D.,	Associate, Chemistry.
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H. L. BARNES, B. Sc.,	Assistant, Horticulture.
W. F. KIRKPATRICK,* B. Agr., B. E.,	Assistant, Animal Husbandry.
A. W. RICHARDSON, B. Sc.,	Assistant, Agronomy.

OTHER MEMBERS OF THE STATION STAFF.

P. H. WESSELS, B. Sc.,	Assistant, Chemistry.
F. L. YEAW,† B. Sc.,	Assistant, Chemistry.
J. FRANK MORGAN, M. A.,	Assistant, Chemistry.
F. G. KEYES, B. Sc.,	Temporary Assistant, Chemistry.
NATHANIEL HELME,	Meteorology.
BEULAH A. HOITT,	Stenographer and Accountant.
E. ELIZABETH MEEARS,	Stenographer and Librarian.

The publications of the Station will be mailed free on request to any one in Rhode Island interested in agriculture. The Station desires the co-operation of the farmers of the State in the work of investigation, and any facts of special interest concerning animal or vegetable growth or disease are solicited. Visitors are always welcome. Railway station, telegraph, express, and post-office—Kingston Rhode Island. Long distance telephone, Narragansett Pier exchange.

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*Expert in the Bureau of Animal Industry, U. S. Department of Agriculture. Engaged in co-operative work between the Bureau and the Station.

†Appointed special agent in the Bureau of Soils, U. S. Department of Agriculture, Washington, D. C. Engaged in co-operative work between the Bureau and the Station.

LETTER OF TRANSMITTAL.

To His Excellency, James H. Higgins, Governor, and the Honorable the General Assembly of the State of Rhode Island, at its January Session, 1907.

KINGSTON, R. I., January 1, 1907.

I have the pleasure to present herewith, in compliance with the statute of the State and the Congressional act of March 2, 1887, the Report of the Director of the Rhode Island Agricultural Experiment Station for the year ended June 30, 1906.

Respectfully submitted,

For the Board of Managers,

CHARLES DEAN KIMBALL,

President.

AGRICULTURAL EXPERIMENT STATION

OF THE

RHODE ISLAND COLLEGE OF AGRICULTURE AND MECHANIC ARTS.

KINGSTON, R. I., June 30, 1906.

HON. CHARLES DEAN KIMBALL,
President, Board of Managers.

SIR:—I have the honor to transmit herewith the Nineteenth Annual Report of the Rhode Island Agricultural Experiment Station for the year ending June 30, 1906.

Respectfully yours,
H. J. WHEELER,
Director.

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DIRECTOR'S REPORT.

REPORT OF THE DIRECTOR.

KINGSTON, R. I., August 15, 1906.

To Honorable Charles Dean Kimball, President of the Board of Managers of the Rhode Island College of Agriculture and Mechanic Arts.

SIR:—Below will be found a report concerning the work of the Experiment Station for the year ended June 30, 1906.

DIVISION OF CHEMISTRY.

The Division of Chemistry has continued the collection and analysis of commercial fertilizers and commercial feeding-stuffs. Two Bulletins have been published during the year on fertilizers, and one on feeding-stuffs.

It is believed that the publication of these analyses, especially the latter, has exerted an especially beneficial influence, and the correspondence with manufacturers whose goods were found to be faulty has in most cases resulted in immediate steps being taken to correct the condition.

That such efforts are necessary in order to keep the goods up to a proper standard must be evident to anyone who examines with care the recent Bulletin No. 112.

Aside from the routine analytical work in connection with other divisions, the most important analyses of the year have been made in connection with the study of the assimilability or actual agricultural value of organic nitrogen derived from a considerable number of different sources, and in the course of the study of the functions, and the agricultural value, of certain sodium salts.

In all the work of the division I have been ably assisted by Doctor Hartwell, who has had the entire responsibility for all of the laboratory details and for the continuation of the work on the assimilability of nitrogen.

Further details concerning special work of the Chemical Division can be found in an article on the sodium investigations, which is to be found in the subsequent pages.

DIVISION OF HORTICULTURE.

The Horticultural Division has continued the experiments outlined in my report of the previous year. In addition an experiment has been begun for the purpose of testing various individual grasses, mixtures of grasses, and combinations of certain grasses with common white clover, in order to ascertain their relative adaptability for ordinary lawns, golf links, and polo grounds. In connection with this trial it is designed to test the influence of various manurial combinations upon the permanence of the clover and of the several grasses.

Further details of the work of the division may be found embodied in the special report of the Horticulturist, Professor Card, which is to be found in the subsequent pages.

DIVISION OF AGRONOMY.

The general work of the Division of Agronomy has been continued in essentially the lines laid down in my former report. It consists in the study of seven different rotations of crops, a trial of the relative efficiency of several different phosphatic manures, a study of the agricultural value of sodium salts, the influence of lime upon the growth of miscellaneous plants, the most economical mixtures of manures for use in grass culture, the efficiency of Peruvian guano for grass and certain hoed crops, variety tests of early field corn and of potatoes, experiments in continuous corn and grass culture, and tests of various fungicides and insecticides.

My associate in this work, Mr. George E. Adams, has entire charge of all the details, and has carried on independently the experiments with potato varieties, potato spraying, and fungicides.

DIVISION OF ANIMAL HUSBANDRY.

The energies of the Division of Animal Husbandry, which is under the direction of Doctor Curtice, have been devoted, as heretofore, to questions of incubation and brooding, in connection with ordinary fowl. In addition experiments have been begun with guinea fowl, and pheasants, in the same direction. At the same time it was hoped to learn some of the causes of the losses of young pheasants, to study the methods of avoiding loss, and to ascertain if these two kinds of birds are immune to the blackhead disease (*Entero-hepatitis*, Smith) which is so fatal to the turkeys.

The chief work of the division has been in ascertaining, if possible under what conditions turkeys could be reared successfully, the means by which the black-head disease is communicated, and how it can be most successfully combated.

In this connection the attempt is being made, in coöperation with the Bureau of Animal Industry of the U. S. Department of Agriculture, to ascertain if wild turkeys are immune to the disease and if it is not possible to breed immune birds which shall possess high economic value for various purposes.

Great difficulty has been experienced in securing wild stock, owing to the fact that in several states and territories the laws prohibit the exportation of the live birds. Nevertheless the local laws permit the shooting of wild turkeys for several weeks during the year. In order to meet this difficulty it has become necessary to appeal to the local authorities to take steps to have the laws modified so as to permit the capture of wild turkeys in limited numbers for scientific breeding purposes. Owing to the fact that the legislatures in most cases meet only biennially, much time and patience is required to secure help by way of local legislation.

Doctor Curtice now has a Bulletin in preparation which will set forth some of the results obtained in connection with the turkey work, and during the coming year it is hoped that additional matter concerning turkeys, and also the results of the unpublished work on incubation and brooding, may be issued.

THE ADAMS ACT.

Through the energy of the late Hon. H. C. Adams, Representative in Congress from Wisconsin, aided by the farmers' organizations throughout the United States, an act was passed by Congress, on March 16, 1906, increasing the appropriation for each Agricultural Experiment Station in the United States $5,000 for the fiscal year ending June 30, 1906; $7,000 for the following fiscal year, and so on until the additional annual appropriation shall reach the sum of $15,000; or in other words until the total annual appropriation including the fund derived from the Hatch act, shall reach the sum of $30,000 per annum.

Under a subsequent ruling of the Comptroller of the Treasury it was held that the first appropriation was not legally made to begin before the fiscal year beginning July 1, 1906. In view of this a rider was attached to the Agricultural Appropriation bill, interpreting the act in such a way as to make the fund available from and after March 16, 1906. This bill was not, however, passed until a day or two before the close of the fiscal year, on which account, due to the lapsing of the fund on June 30 if unexpended, some of the Stations are likely to lose the whole or a part of the first year's appropriation. By the passage of this act this Station will have at disposal for the coming year the sum of $22,000 for experimental purposes, in addition to aid by way of coöperation on the part of the Bureau of Animal Industry of the U. S. Department of Agriculture to the extent of $2,150 and on the part of the Bureau of Soils to the extent of furnishing two men for several months for investigation work.

Under the interpretation of the authorities in Washington the

Adams fund can be applied only to paying the necessary expenses of conducting *original researches or experiments bearing directly on the agricultural industry of the United States. Expenses for administration, care of buildings and grounds, insurance, office furniture and fittings, demonstration and institute work, and travelling in connection with administration duties, the printing and issuing of bulletins and reports, can not be paid from this fund.*

NEEDS OF THE STATION.

Owing to the increased need of laboratory and office room in consequence of the passage of the Adams act, it will probably soon become necessary for the College to withdraw entirely from the Station building. Heretofore one of the rooms has heen used exclusively as an agricultural lecture room and another has been used for a portion of the time as a physical soil laboratory and geological lecture room. In addition, also, Mr. Stene, who is in charge of the extension and demonstration work of the College, has maintained his office in the building and also the heads of the Divisions of Agronomy and Animal Husbandry of the College.

A most pressing need at the present time is a suitable fire and moisture proof storage vault, in which all of the records of the experimental work can be kept. The present safe is practically full, and, furthermore, it does not afford proper protection in case of fire.

It is obviously undesirable to accumulate experimental data, secured at a cost of many thousands of dollars per year, without providing a place where they can be secure from the danger of fire. In addition to the storage vault there should be provided a suitable office for the Director, where it is possible to do consecutive work without the continual disturbance which results when he is obliged to do all of his work, as at present, in the chief business office of the Station, which must of necessity be always open to the Station staff and to the public. In this particular it is a matter of economy to furnish the same facilities for writing and executive work which are provided in every well-ordered business office and which are usually found in other experiment stations.

It is of vital importance to the Station at this time that additional land should be set aside for use in connection with the experiments in agronomy and horticulture.

PUBLICATIONS OF THE YEAR.

The following is a list of the publications issued during the year:

Eighteenth Annual Report. pp. 179 to 352.

Bulletin No. 108, "Analyses of Commercial Fertilizers." 12 pp.

Bulletin No. 109, "A Comparison of the Results Obtained by the Method of Cultures in Paraffined Wire Pots with the Field Results on the Same Soil." 22 pp.

Bulletin No. 110, "Commercial Fertilizers." 16 pp.

Bulletin No. 111, "Potatoes." 16 pp.

Bulletin No. 112, "Commercial Feeding-Stuffs." 22 pp.

Bulletin No. 113, "Continuous Corn Culture." 18 pp.

Bulletin No. 114, "A Test of Nine Phosphates with Different Plants." 23 pp.

CHANGES IN THE STATION STAFF.

On August 21, Mr. W. F. Kirkpatrick, B. Agr., B. E., a graduate of the North Carolina College of Agriculture and Mechanic Arts, was appointed expert in the Bureau of Animal Husbandry of the U. S. Department of Agriculture. He was then detailed to assist in the work conducted here in turkey breeding, in which the Bureau and Station are coöperatively engaged.

On September 1, Mr. George E. Adams, B. Sc., formerly assistant in agronomy was made associate agronomist.

Mr. James W. Kellogg, B. Sc., who had served most acceptably as assistant chemist at the Station for about three years, resigned in January, 1906, to accept a position as chemist in Atlanta, Ga.

On June 5, Mr. Matthew Steel, M. Sc., who had been employed at the Station under appointment as expert in the Bureau of Soils of

U. S. Department of Agriculture in coöperative chemical work concerning the action of sodium salts upon soils and plants, tendered his resignation in order to take up advanced studies at Columbia College, New York. Mr. J. P. Gray, B. Sc., who had been connected with the Station as assistant chemist, also tendered his resignation, which went into effect on June 9.

The position as stenographer and librarian, made vacant by the resignation of Miss Martha Vickery at the close of the previous fiscal year, was filled by the appointment of Miss Alethea R. Puffer, A. B., a graduate of Mt. Holyoke College, who in turn resigned, on February 1, 1906, to accept a more lucrative position elsewhere. Subsequently Miss E. Elizabeth Meears was appointed to the position thus made vacant.

On April 1, Mr. F. L. Yeaw, B. Sc., a graduate of the Massachusetts Agricultural College, was appointed assistant in agronomy. Early in May, 1906, he was appointed expert in the Bureau of Soils of the U. S. Department of Agriculture and was detailed to this Station to assist in coöperative soil tests in which the Bureau was lending the Station its aid.

Mr. A. W. Richardson, B. Sc., a graduate of the Maine State University, was appointed assistant in agronomy on April 22, 1906.

On May 7, Mr. J. F. Morgan, M. Sc., a graduate of St. Lawrence University, was appointed assistant chemist; and on June 1, Mr. Fred G. Keyes, who was about to graduate with the degree of B. Sc. from the Rhode Island College of Agriculture and Mechanic Arts, was appointed temporary assistant in chemistry.

On October 1, 1905, M. A. Blake, B. Sc., who had served most acceptably as assistant horticulturist, resigned to accept a more remunerative position elsewhere, and H. L. Barnes, B. Sc., was appointed in his place.

COÖPERATIVE WORK.

The work on soils and in the breeding of turkeys in coöperation with the Bureau of Soils and the Bureau of Animal Industry of the U. S. Department of Agriculture has been continued, and it is hoped the coming autumn or winter to publish two or more bulletins giving an account of some of the results thus far secured.

ACKNOWLEDGMENTS.

It gives me pleasure to acknowledge the loyal aid of Doctors Curtice and Hartwell, also of Professors Card and Adams, in carrying forward the work of the year. To Doctor Hartwell I am especially indebted for aid in the correction of manuscript and proof sheets. To the other members of the Station staff, whom it would be a pleasure to mention individually, a very large measure of credit is due for daily duties faithfully performed, and all are to be commended for the most admirable spirit of loyalty to the Station, for their continued devotion to its best interest, and for their attitude, by which the relations of one with another have been pleasant and thus conducive to good work and to the general credit of the Station.

HORTICULTURAL DIVISION.

REPORT OF THE HORTICULTURAL DIVISION.

FRED W. CARD, M. A. BLAKE, AND H. L. BARNES.

DESTROYING CHARLOCK IN GRAIN FIELDS.

The charlock, or wild radish, forms one of the most troublesome pests in grain fields in this region.

As a part of his student-investigation work in the College, Mr. A. E. Wilkinson, one of our agricultural students, undertook to determine the effect of spraying a field of oats and peas badly infested with charlock. Two solutions were used: one containing 60 pounds of copperas (iron sulfate) to 40 gallons of water, the other containing 12 pounds of blue vitriol (copper sulfate) to 40 gallons of water. A potato sprayer was used in this work. The copper sulfate was applied June 8, the iron sulfate June 14. The charlock was then in bloom, and too tall to be effectually reached by the spray with the machine used.

On June 14, when the copperas was applied, the part previously sprayed with copper sulfate showed that the charlock leaves were apparently killed where hit by the spray. Many of the buds and blooms were also killed. Tips of many of the oat leaves were also killed, and some leaves of the peas were hurt, usually the lower ones. The injury did not appear to be serious enough to materially check the growth of the oats or peas. The spraying seemed to be even more effective in destroying a common weed, resembling smartweed, belonging to the genus *Polygonum*, which was abundant in the field. The plants of this weed were still small, and the leaves appeared to be easily killed by the spray. Later observations proved that the charlock had been well killed out in lines across the field where it had been struck by the spray. A machine working further from the ground would have been more effective at that time.

In the portion sprayed with copperas (iron sulfate) the oats and peas appeared to be injured more than the charlock. Some charlock leaves were killed, but not enough to prevent its blossoming in a normal manner. The peas in particular had many of the lower leaves blackened and killed. Many of the tops of the oats were also killed.

At the time the oats and peas were harvested for hay the charlock was very little in evidence, apparently having been considerably reduced by the spraying. Judging by this experience, a spray of copper sulfate in the strength here used, if applied in the earlier stages of growth, when the plants could be more effectually reached, would prove decidedly effective in destroying this plant, with no permanent injury to the grain crop.

GRAFTING-WAX.

In the spring of 1905 a number of formulas for making grafting-wax were tried in the laboratory. We were led to do this from getting a lumpy wax in some cases. The chief object was to determine the cause of this lumpy condition.

A Common Wax.

4 lbs.	resin.
2 lbs.	beeswax.
1 lb.	tallow

This is a common formula and gives an excellent wax, very smooth, but rather too hard when it cools. Adding a little tallow to this softens it without making it lumpy.

A Wax With Less Resin.

3 lbs.	resin.
3 lbs.	beeswax.
2 lbs.	tallow.

Although recommended by high authority as excellent, in our experience this formula made a very sticky, lumpy wax, being soft but so sticky that it could hardly be worked at all. Adding more resin improved it, taking away the stickiness and most of the lumps. Adding tallow made it very sticky and lumpy again, so much so that it could not be worked.

An Oil Wax.

4 lbs. resin.
2 lbs. beeswax.
1 pint linseed oil.

This gave a soft, sticky, and very lumpy wax. Adding resin took away the stickiness and nearly all the lumps, making it smooth but hard. The addition of more oil, after extra resin had already been added, made it softer but retained the smoothness and freedom from lumps. The addition of beeswax to this lumpy wax made from oil did not change it to any extent.

A Smaller Proportion of Oil.

100 grams resin.
50 grams beeswax.
20 grams linseed oil.

This makes a soft pliable wax, appearing somewhat dry and a little granular, but hardening into a very nice wax. It is not so hard as the 4–2–1 tallow wax, but is possibly a little too hard for most convenient use.

Resin 4, paraffine 2, oil 1 (by weight), made a lumpy wax, apparently too soft.

Resin 4, paraffine 2, tallow 1, gave a very nice, soft, white wax, but with a few lumps. This would break when first being worked, and was too soft and sticky. It would probably run with heat.

A mixture of resin and tallow alone gave a very lumpy wax, sticky and ductile.

Two parts resin to one part beeswax seems to be the best proportion to use. More or less tallow or oil can be used to render the wax harder or softer as desired. Adding tallow to a good wax does not bring lumps if not used in too great quantities. Adding resin to a soft lumpy wax will render it smooth and pliable. Oil waxes are lighter in color than tallow waxes.

LAWN EXPERIMENT.

An experiment with lawn plats was begun in the summer of 1905. with the active advice and coöperation of the Director The object of this was to test the influence of different fertilizers upon the permanence of white clover and certain grasses and to compare the adaptability of different grasses and mixtures for lawns, golf links. and polo grounds.

A triangular piece of land at the end of the horticultural grounds afforded opportunity for twenty-five plats each fourteen by twenty feet in size, with paths two feet wide between. Partial plats adjoining the diagonal boundary line afforded opportunity for further plats varying in size, and making thirty-three in all.

The plan of the experiment was as follows:

I. *Fertilizer furnishing an acid residue.*—Sulfate of ammonia. acid phosphate. muriate of potash.

Plat 1. Kentucky blue-grass (*Poa pratensis*).
" 2. Rhode Island bent (*Agrostis canina*).
" 3. Redtop (*Agrostis alba*).
" 4. Red fescue (*Festuca rubra*).
" 5. Mixture No. 1: Kentucky blue-grass, Rhode Island bent, redtop, white clover.
" 6. Mixture No. 2: Rhode Island bent, redtop, red fescue.
" 7. Henderson's lawn grass.

II. *Fertilizer furnishing an alkaline residue.*—Basic slag, muriate of potash. nitrate of soda.

Plat 8. Kentucky blue-grass.
" 9. Rhode Island bent.

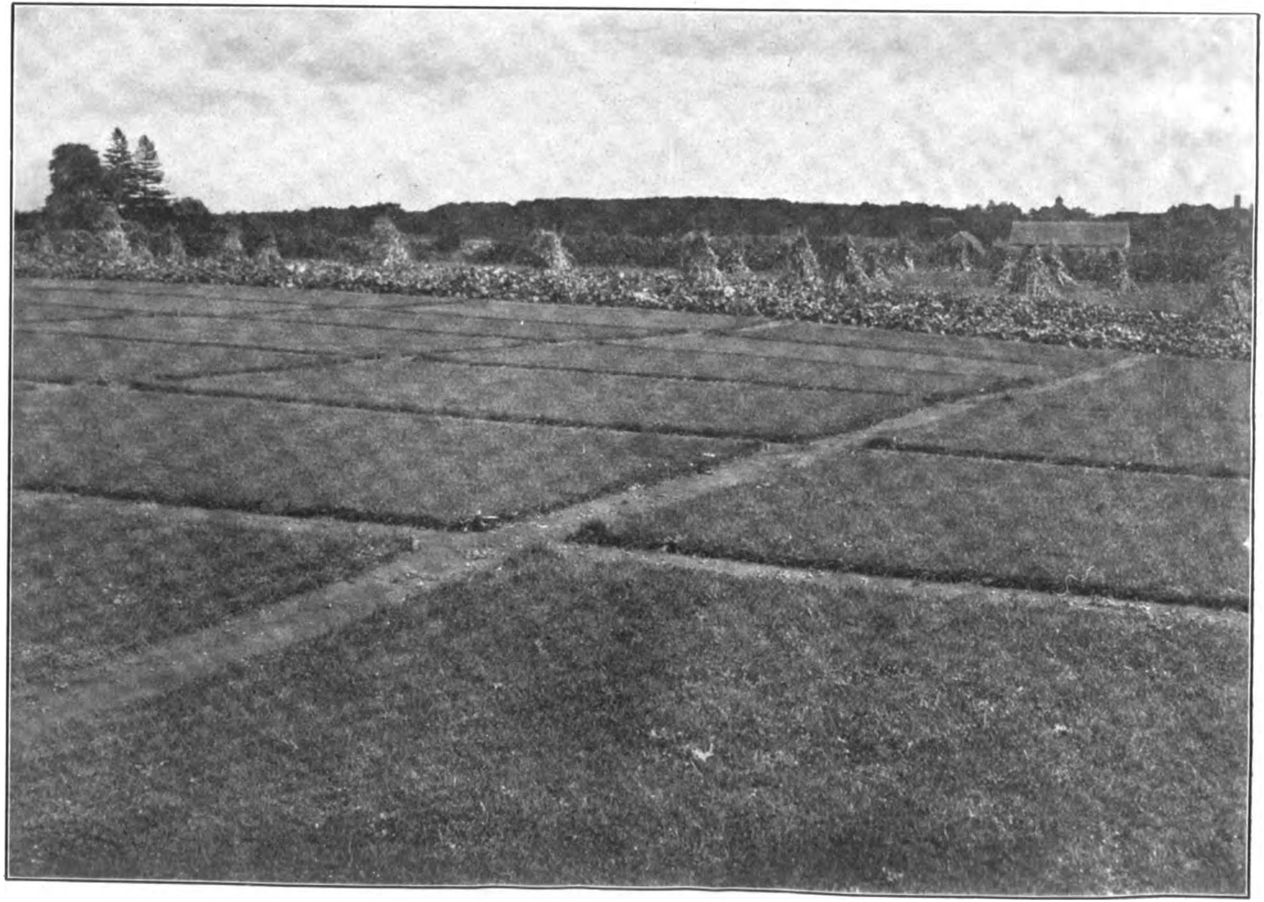

Fig. 1.—The Lawn Plats.

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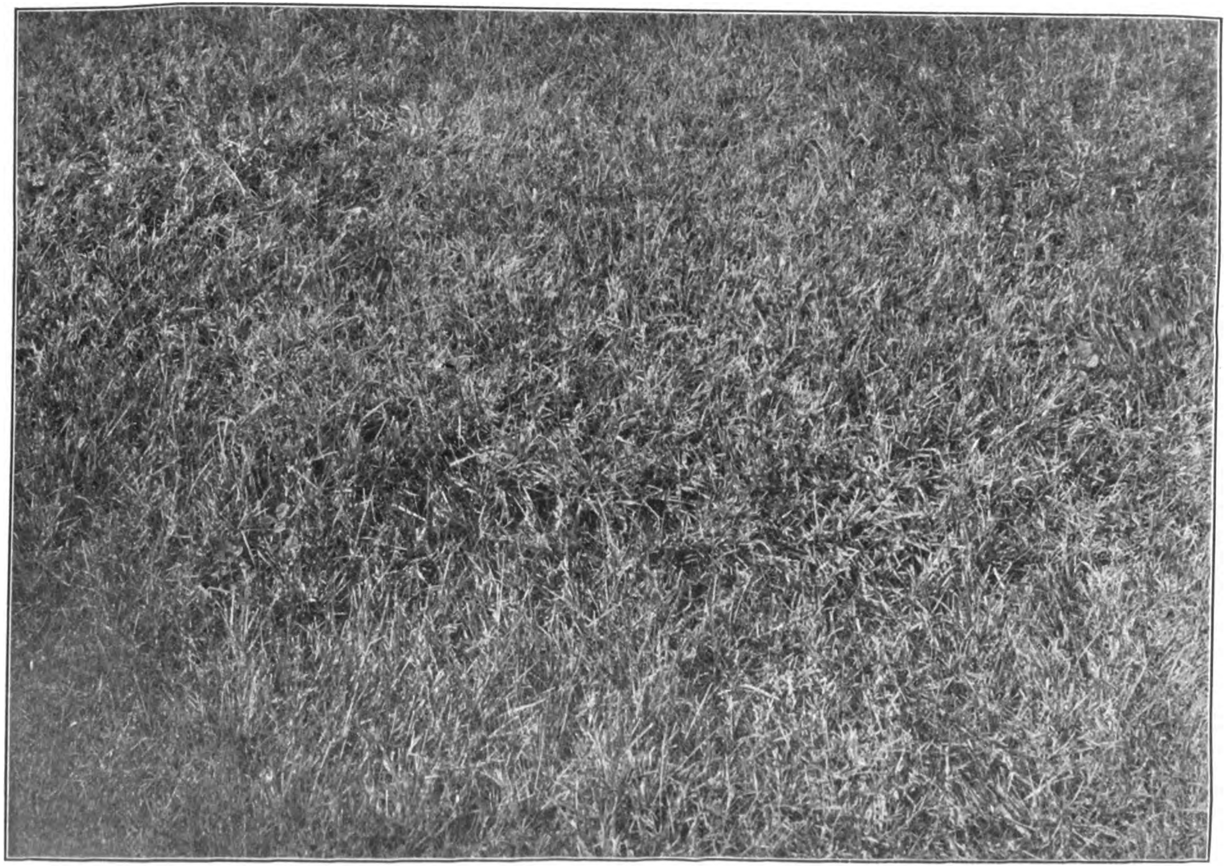

FIG. 2.—Rhode Island Bent.

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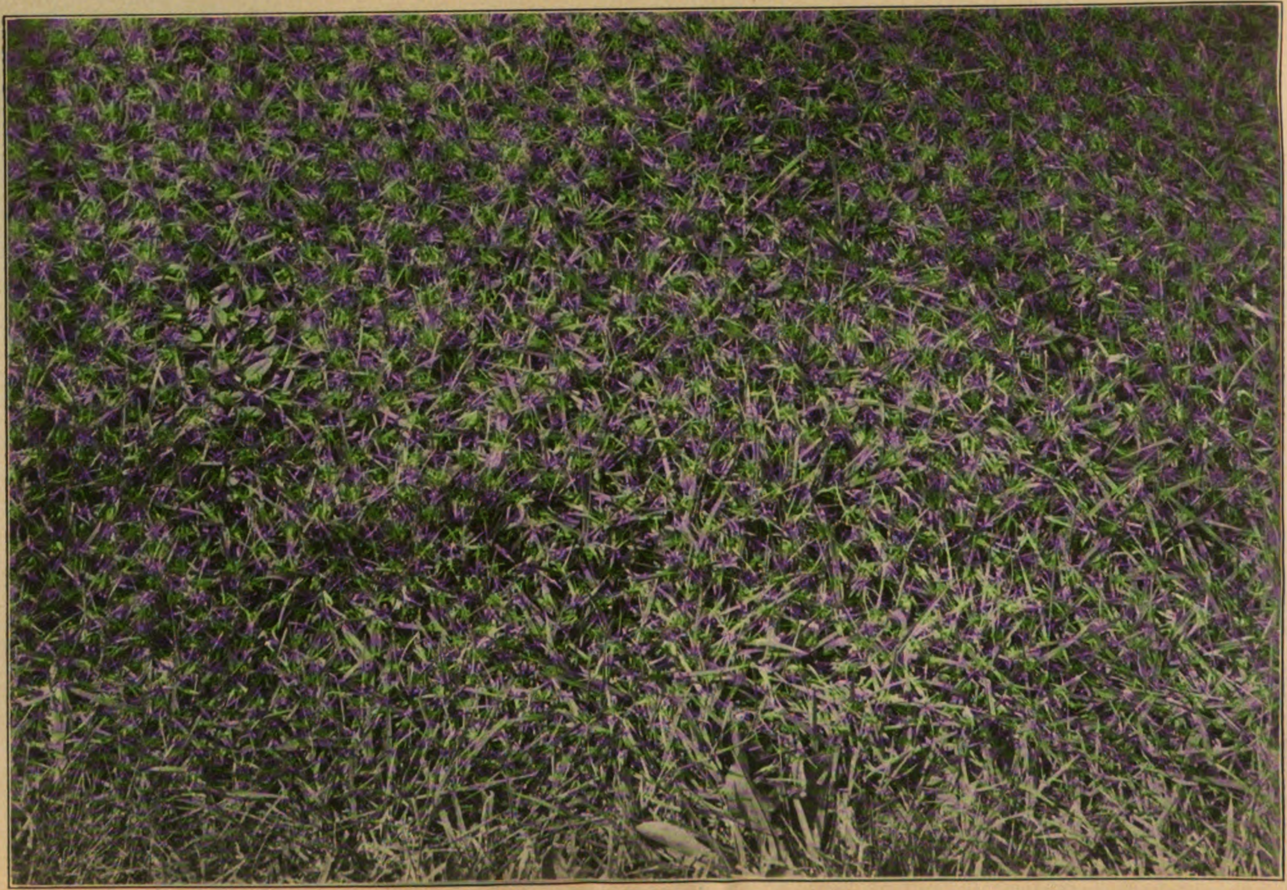

FIG. 3.—Redtop.

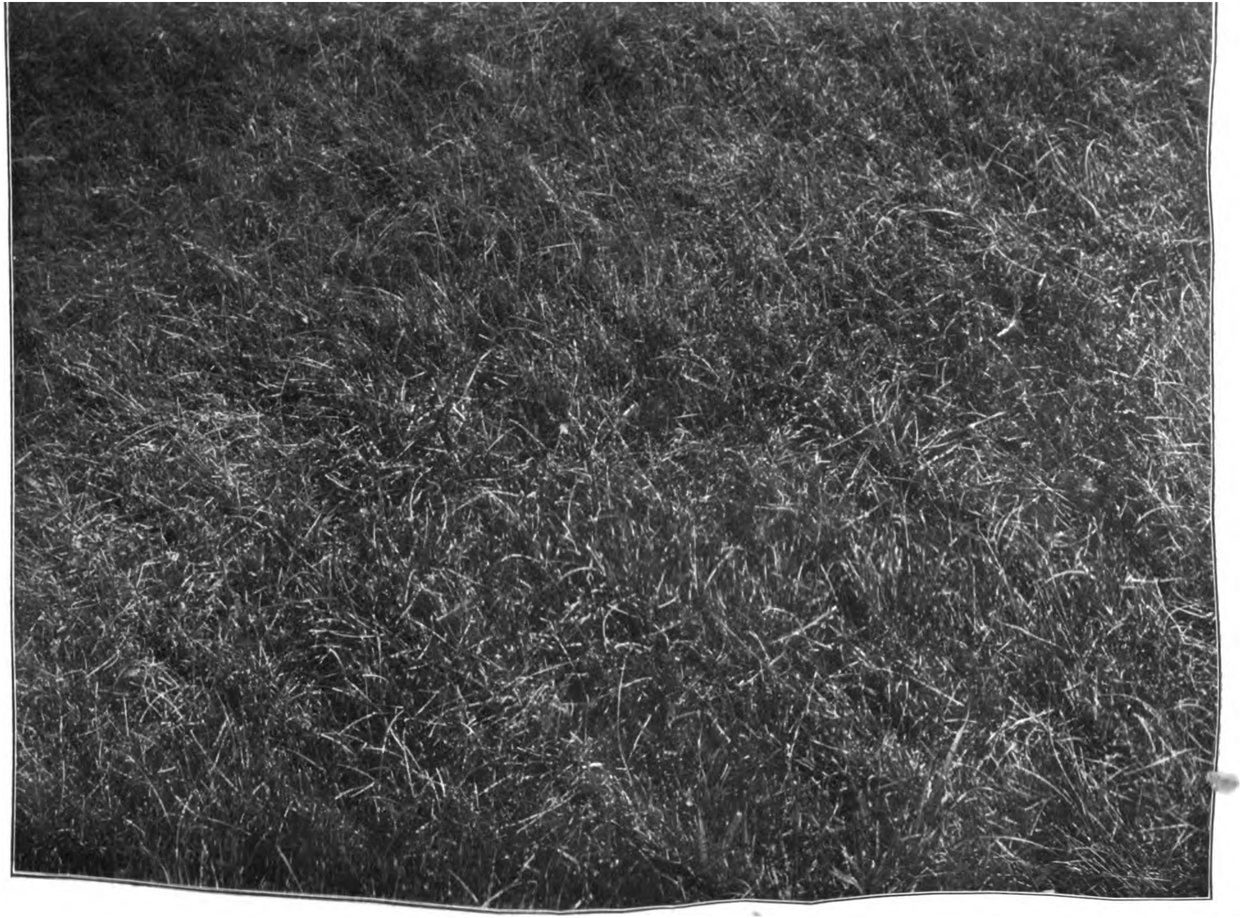

FIG. 4.—Red Fescue.

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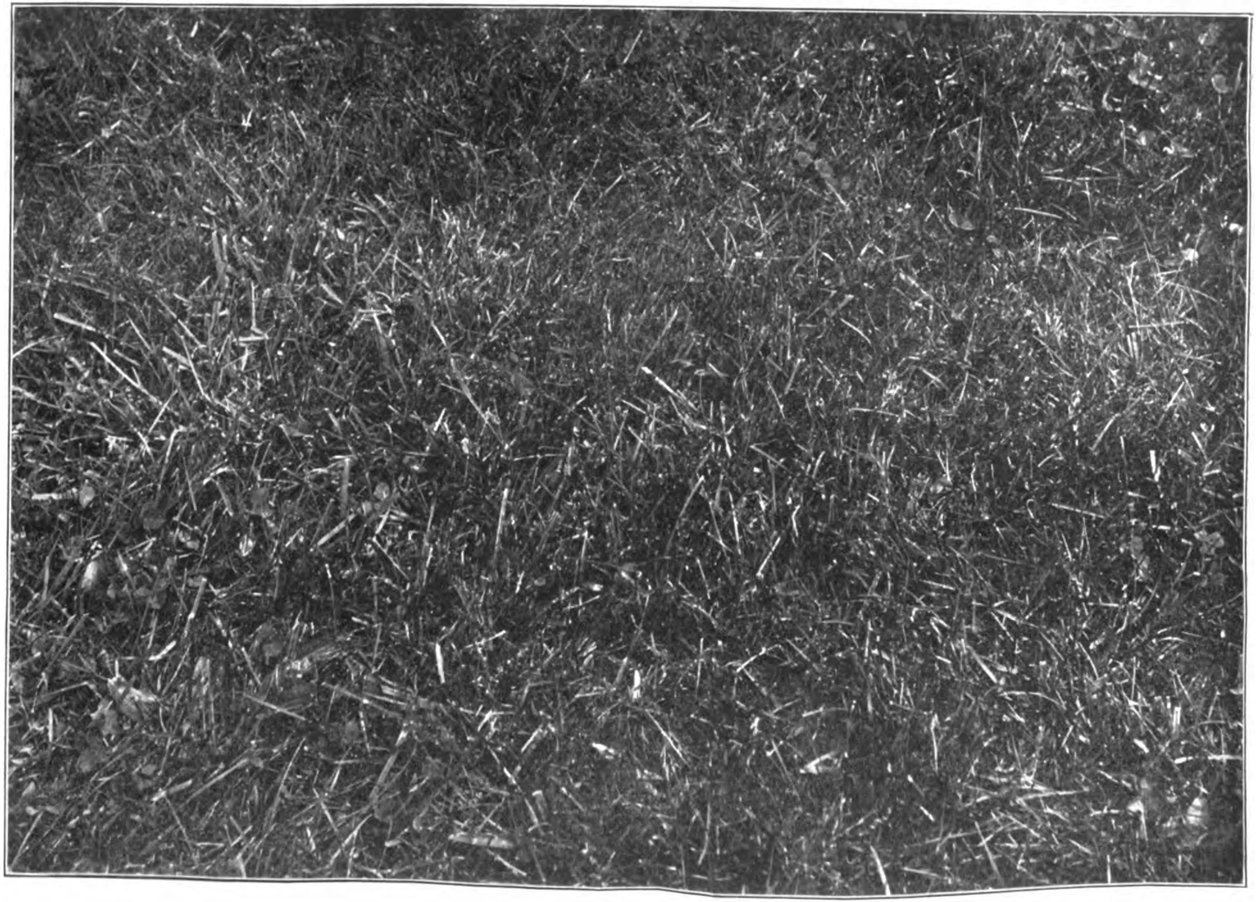
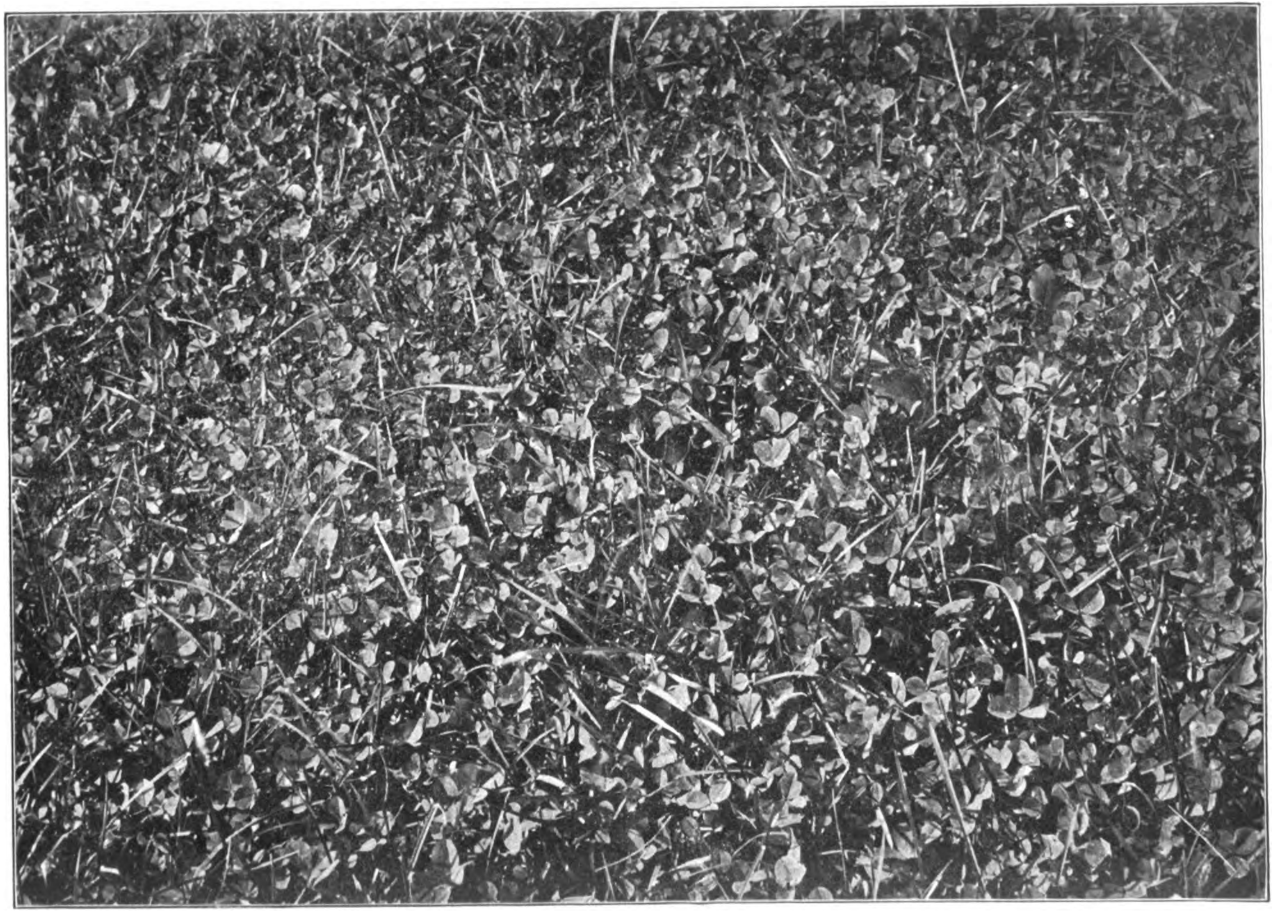


FIG. 5.—Grass Mixture No. 1. Kentucky Blue-grass, Rhode Island Bent, Redtop, and White Clover in equal parts by weight



Plat 10. Redtop.
" 11. Red fescue.
" 12. Mixture No. 1: Kentucky blue-grass, Rhode Island bent, redtop, white clover.
" 13. Mixture No. 2: Rhode Island bent, redtop, red fescue.
" 14. Henderson's lawn grass.

III. *Fertilizer furnishing a nearly neutral residue.*—Acid phosphate, muriate of potash, nitrate of soda, ground bone.

Plat 15. Kentucky blue-grass.
" 16. Rhode Island bent.
" 17. Redtop.
" 18. Mixture No. 1: Kentucky blue-grass, Rhode Island bent, redtop, white clover.
" 19. Henderson's lawn grass.

IV. *Fertilizer tests.*—Grass mixture No. 1.

Plat 20. Acid fertilizer (sulfate of ammonia, acid phosphate, muriate of potash), with one-third ration of nitrogen.
" 21. Acid fertilizer, with one-third ration of phosphoric acid.
" 22. Acid fertilizer, with one-half ration of potash.
" 23. Acid fertilizer, with one-half ration of potash and one-third ration of nitrogen.
" 24. Alkaline fertilizer—Nitrogen from dried blood (dried blood, basic slag meal, muriate of potash).
" 25. Acid fertilizer.—Potash from sulfate. (Sulfate of ammonia, acid phosphate, sulfate of potash.)

V. *Additional grasses.*—Partial plats. Neutral fertilizer (acid phosphate, muriate of potash, nitrate of soda, ground bone).

Plat 26. Thorburn lawn-grass.
" 27. Thorburn lawn-restoring mixture.
" 28. Thorburn putting-green mixture.
" 29. Thorburn golf-links mixture.
" 30. Henderson terrace-sod mixture.
" 31. Henderson tough-turf mixture.
" 32. Creeping bent (*Agrostis stolonifera*).
" 33. Canada blue-grass (*Poa compressa*).

The fertilizer ration used in all cases, no matter what the source of the materials, was as follows:

	Per acre.	*Per plat.*
Actual nitrogen	50 lbs.	5.14 ozs.
Actual phosphoric acid	60 "	6.17 "
Actual potash	150 "	15.42 "

The amount of seed used was six ounces per plat, equivalent to 58.3 pounds per acre. The area of each partial plat was calculated so that the fertilizer and seed were applied at the same rates per acre as in the full sized plats.

Of the seed used, the following kinds were obtained from J. M. Thorburn & Company: Kentucky blue-grass, redtop, red fescue, white clover, creeping bent, Canada blue-grass, Thorburn lawn-grass, Thorburn lawn-restoring grass, Thorburn golf-links mixture, Thorburn putting-green mixture. The remaining kinds, consisting of the following, were obtained from Peter Henderson and Company: Rhode Island bent, Henderson's lawn-grass, Henderson's terrace-sod lawn-grass, Henderson's tough-turf lawn grass.

The land, which had been under the plow for several years previously, was kept well tilled during the early part of the season so as to be in excellent condition for seeding.

The plats were fertilized and seeded on August 11, 1905; the seed being raked in by hand and the ground rolled with a hand roller.

The plats were not mowed during the fall of 1905. Some of them made so much growth that spots were killed out by the grass that remained on them during the winter.

Fertilizer of the same amount and character as that applied at the time of seeding was applied to the surface May 21, 1906.

The following notes explain the character of lawn resulting from the different methods of treatment as observed in the autumn and early summer:*

Kentucky Blue-grass.—This grass did not make a strong start at the beginning, though apparently germinating well and being thick on the ground. Plat 8 was quite weedy at the south end, where it extended upon an old roadway. A pronounced yellowish tinge was apparent during the autumn, but in spring the appearance was good.

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*Later observations modify some of these impressions.

Rhode Island Bent.—This made a very fine, thick growth in the fall, though somewhat unevenly sown. A bluish tinge was apparent. It gave a very fine, velvety turf in the spring, but somewhat spotted from the dead grass which showed through.

Redtop.—This proved to have been unevenly sown, but made a strong growth, giving a good, green appearance in the fall. At the beginning of the summer of 1906 it appeared fairly even, but coarse in texture as compared with Kentucky blue-grass, and especially in comparison with Rhode Island bent.

Red Fescue.—This grass is so fine that the plats appeared bare and thin during the autumn, but the following spring they seemed very good, the color then being dark green. The plats showed a slight admixture with coarser grasses, chiefly velvet grass or meadow soft grass (*Holcus lanatus*).

Mixture No. 1.—Kentucky blue-grass, Rhode Island bent, redtop, white clover. This mixture made an excellent start, producing a lawn quickly. The white clover was very noticeable in autumn. In spring the lawn was very good.

Henderson's Lawn-grass made a very prompt showing, owing to the presence of a coarse, slender, shiny grass which later proved to be perennial rye-grass. The finer grasses were not very thick; this one being most prominent. The following spring these plats appeared coarse and less attractive than most of the others.*

Mixture No. 2—.Rhode Island bent, redtop, red fescue. This mixture started well and produced a good lawn; the grass appearing fine and short in the autumn.

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* The final judgment as to the relative merits of all of the mixtures and individual grasses must be delayed for possibly several years.

No noticeable differences could be detected in plats Nos. 20 to 25, which received varying amounts of different fertilizer ingredients.

Thorburn Lawn-grass.—This made a fine start, the grass being thick and vigorous, with good, dark-green color. It made a good, fine turf the following spring.

Thorburn Lawn-restoring Mixture.—This made a strong, vigorous growth in autumn, being tall and thick, with a yellowish-green tinge, but coarse in appearance the following spring.

Thorburn Putting-green Mixture.—This was similar in appearance to the lawn-restoring mixture, but made a good growth.

Thorburn Golf-links Mixture, Henderson's Terrace-sod Mixture, and Henderson's Tough-turf Mixture were all similar in appearance to Henderson lawn-grass, owing to the presence of perennial rye-grass, which, being a strong grower, makes a quick showing.

Creeping Bent.—A fine, short grass with good color, which started well and gave promise of a good turf the following spring.

Canada Blue-grass.—A very fine, short grass which makes the lawn look bare at the beginning, but which produced a nice, even blue lawn early in spring.

A MARKET-GARDEN ROTATION

This experiment, as explained in the annual report for 1905, is designed to compare stable manure with chemicals in the growing of market-garden crops, a cover-crop being introduced wherever possible in the plat upon which chemicals are used.

The experiment was begun in 1904, the crop that year being corn followed by beans on part of each plat and beans followed by corn on the remainder.

Crimson clover was sown in the plat receiving chemicals, August 19, 1904. A fair amount of this lived through the winter and was allowed to grow until the land was plowed, which was done June 7, 1905.

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The stable-manure plat received one cord of stable manure and the other plat 200 pounds of chemicals as in the previous year, this being at the rate of ten cords of manure and one ton of chemicals per acre. In the previous year the nitrate of soda was applied at intervals but for the tomato crop it was thought best to apply the whole amount with the other fertilizer, which would be the common custom in commercial tomato growing.

Dwarf Stone tomatoes were planted upon both plats June 9, 1905. The plants upon the plat receiving fertilizer made a better start and maintained their superiority throughout the season. The yields harvested from the two plats were as follows:

Date.	Plat fertilized with stable-manure.	Plat fertilized with chemicals.
Aug. 29	5 lbs. 4 ozs.	9 lbs. 2 ozs.
“ 31	4 “ 3 “	7 “ 10 “
Sept. 1	11 “	1 “ 10 “
“ 5	20 “ 2 “	29 “ 8 “
“ 8	20 “	36 “ 13 “
“ 9	58 “	65 “
“ 13	29 “	65 “ 4 ozs.
“ 16	32 “ 10 ozs.	65 “ 2 “
“ 19	62 “	62 “
“ 21	116 “ 8 ozs.	159 “ 8 ozs.
“ 23	179 “	313 “
“ 26	133 “	161 “
“ 28	53 “	115 “
“ 30	50 “	62 “ 12 ozs.
Oct. 5	68 “	58 “
“ 7	130 “	108 “
“ 11	35 “	28 “
Marketable tomatoes	996 lbs. 6 ozs.	1,347 lbs. 5 ozs.

On the date of the last picking, October 11, all tomatoes were removed from both plats and weighed. In addition to those which were ripe and are included in the above list, the following were obtained:

	From stable-manure plat.	From chemical plat.
Green tomatoes	439 lbs.	242 lbs.
Rotten tomatoes	255 "	171 "

It will be seen from the above figures that the plat receiving chemicals produced 350 pounds, 15 ounces, more marketable tomatoes than the one receiving stable manure, an increase of thirty-five per cent. There were 197 pounds more green tomatoes when the plats were cleaned up, October 11, on the one which had received stable manure than on the one which had received chemicals. There were also eighty-four pounds more of rotten tomatoes upon the former plat. While the difference in total yields, including marketable, green, and rotten tomatoes, is not great, being only 69 pounds and 7 ounces greater from chemicals than from manure, the difference in the quantity of marketable tomatoes is decided.

Reference to the weights harvested at different dates will show that a larger proportion of ripe fruit was obtained early in the season from the use of chemicals than from the use of stable manure. A comparison of the first five pickings shows that during this early fruiting period 67½ per cent. more fruit was obtained from the plat treated with chemicals than from the other. These results are in harmony with generally accepted views concerning the influence of nitrate of soda in hastening the maturity of tomatoes.

Rye (one peck) was sown and raked in among the tomatoes on the plat treated with chemicals, on August 2, 1905, the other plat being raked over at the same time and in the same manner. This rye was allowed to grow until the plat was plowed the following spring, at which time it had produced a good growth, furnishing a considerable amount of vegetable matter to turn under.

A RASPBERRY SCORE-CARD.

The necessity of making practical notes upon raspberry seedlings produced from crossing different varieties has led to the adoption of a score-card somewhat similar to the one used for strawberries, which was shown in the annual report for 1905. This score-card for raspberries has not been used long enough to prove its merits. Further use may suggest some modifications, but at present it appears to be fairly well adapted to the purpose and is shown here for the possible aid of any who may have similar work to do.

RASPBERRY.

Variety...

SCALE-POINTS 10-Perfect.

Plant.

Vigor
Disease Resistance

Fruit.

Productiveness
Appearance
Firmness
Size
Quality
Cohesion

DESCRIPTION.

Plant.

Habit
Propagation

Fruit.

Form
Flavor
Season
General Notes
Color
Drupelets

Date.....................
Observer

STERILIZED SOIL.

The work with sterilized soil was continued in 1905.* The different methods of treatment under test, as in 1904, were as follows:

1, Unsterilized; 2, Sterilized and handled while hot; 3, Sterilized and handled cold; 4, Sterilized and sprinkled lightly with rich, unsterilized soil to introduce soil organisms; 5 Sterilized and treated with nitrate of soda at intervals.

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* See annual report for 1905, page 204.

Galvanized iron pots not being available in 1904, large flower-pots were used for the experiment. These were objectionable from the fact that in summer weather in the open air they permit the soil to dry out very rapidly. The soil used was taken from the north garden, and was in only a fair state of fertility. This was sterilized May 18, 1905, and the pots filled according to the plan outlined, four pots being used for each part of the experiment, two being planted with French Breakfast radish and two with Hanson lettuce. The garden soil used to sprinkle upon the four pots treated in this way was also taken from the north garden, May 31.

As the work progressed it was noticed that the unsterilized soil appeared to dry out sooner than the others. Some weeds appeared in this pot, as would be expected. Pots containing sterilized soil which was handled while hot appeared to retain moisture better than any of the others. None of the lettuce thrived well. Nearly all the radishes in one pot of unsterilized soil were eaten off by some small insect, and more seed was planted June 6. Pot No. 2 of the unsterilized soil seemed to be in advance of any of the others with Nos. 1 and 2 of sterilized soil handled hot occupying second place. On June 12 the radishes were thinned to nine in each pot.

The following observations as to maturity were made June 17. Pot No. 2 of unsterilized soil had six radishes mature, 2 half mature, and one small. In sterilized soil sprinkled with garden soil none were yet half mature. In sterilized soil which had been handled cold four radishes were half mature, the remainder being small. In the sterilized soil handled hot five were mature, five two-thirds mature, the remainder half mature. In sterilized soil fertilized with nitrate of soda two were half mature, the remainder small.

The radishes were harvested June 27, and the following weights were obtained:

	Total yield.	Wt. of leaves.	Wt. of roots.
Unsterilized	141.6 grams.*	46.2 grams.	95.4 grams.
Sterilized, handled hot	272.3 "	92.6 "	179.7 "

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*Only two plants were obtained from pot No, 1. the second planting also having failed.

	Total yield.	Wt. of leaves.	Wt. of roots.
Sterilized, handled cold	193.25 grams.	68.4 grams.	124.85 grams.
Sterilized, sprinkled with garden soil	219.15 "	77.4 "	141.75 "
Sterilized, with nitrate of soda added	212.2 "	73.7 "	138.5 "

Radishes obtained from the sterilized soil handled hot were not only larger, as the weights show, but were also brighter in appearance, making a better-looking crop. Those from the unsterilized soil were next in appearance, but not as smooth and bright as from the sterilized. Those from the pots sprinkled with garden soil, which are next in order as to weight, were bright, smooth, and symmetrical, being better in form than those from the unsterilized soil. Those from the sterilized soil with nitrate of soda added were also bright, smooth, and symmetrical, and very uniform in size and shape. Those from the sterilized soil handled cold were more uneven and were not equal in appearance to any of the others.

The lettuce in all pots made a very poor growth, probably due to the pots drying out in the hot weather. That grown in the unsterilized soil was somewhat better than in the others. All lettuce was pulled and the pots planted with rutabaga turnips August 31. Worms ate the leaves of these badly, but all were eaten in about the same proportion. They were pulled and weighed late in the fall with the following results:

	No.	Total weight.	Wt. of root.
Unsterilized	11	.21 lbs.	.08 lbs.
Sterilized. handled hot	10	.29 "	.14 "
Sterilized, handled cold	10	.24 "	.14 "
Sterilized. sprinkled with garden soil	10	.18 "	.09 "
Sterilized, with nitrate of soda added	10	.24 "	.11 "

Marguerite carnations were planted July 6 in the pots from which radishes had been harvested. The pots containing unsterilized soil still appeared to be drier than the others, and those containing sterilized soil handled hot still appeared to hold moisture better than the others. The number of carnations picked from the different lots was as follows:

	September				
	1.	13.	21.	26.	Total.
Unsterilized soil	1	..	..	..	1
Sterilized, handled hot	..	..	..	1	1
Sterilized, handled cold	..	..	1	..	1
Sterilized, sprinkled with garden soil	..	..	..	..	..
Sterilized, with nitrate of soda added	..	1	..	1	2

	October									
	5.	9.	12.	13.	16.	18.	21.	25.	31.	Total.
Unsterilized soil	..	2	1	..	1	1	..	..	..	5
Sterilized, handled hot	1	1	1	..	..	..	..	1	..	4
Sterilized, handled cold	..	..		..	..	..	..	..	..	..
Sterilized, sprinkled with garden soil	..	..	1	1	..	..	..	..	..	2
Sterilized, with nitrate of soda added	..	1	..	..	2	..	1	..	1	5

	November					Total Entire
	6.	9.	10.	14.	Total.	period.
Unsterilized soil	..	..	..	..		6
Sterilized, handled hot	..	..	..	..	..	5
Sterilized, handled cold	..	3	..	1	4	5
Sterilized, sprinkled with garden soil	..	..	..	..	..	2
Sterilized, with nitrate of soda added	1	1	1	..	3	10

The thermometer dropped to 12° above zero and earth froze in some of the pots on the night of Nov. 13, and records were not continued longer.

So far as these tests go, any gain which might be expected to result from the re-introduction of soil organisms into a sterilized soil by sprinkling it with unsterilized soil has not appeared. Handling the sterilized soil while still hot, instead of proving injurious, as has been suggested, appeared to act beneficially.

Tent Covering for Vegetables.

This experiment was continued in 1905 with cauliflower alone, that being the vegetable which in previous experiments had shown the greatest gain from the covering. The land inside the tent, which was 12 x 48 ft. in size, together with the same area outside, was spaded May 27 and cauliflower plants set May 29. The ground outside the tent was very dry, so that the soil was tramped around each plant after it had been set. The plants inside made a much better start and continued to make a better leaf-growth throughout the summer. The ground inside the tent remained moist much longer after rain than that outside.

The following yields were obtained inside the tent:

Date.	Untrimmed.		Trimmed.	
July 19	2 lbs.	6 ozs.	1 lb.	8 ozs.
" 26	6 "	6 "	3 "	12 "
" 27	17 "	4 "	11 "	4 "
" 29	14 "		7 "	2 "
Aug. 2	12 "	10 "	7 "	4 "
" 4	39 "	10 "	24 "	8 "
" 11	89 "	8 "	76 "	
" 17	238 "	9 "	166 "	7 "
" 23	48 "	9 "	21 "	3 "
" 26	57 "	9 "	26 "	
Sept. 5	29 "	3 "	17 "	7 "
" 13	60 "		33 "	
" 15	49 "	3 "	21 "	
Total	664 lbs.	13 ozs.	416 lbs.	7 ozs.

YIELDS OUTSIDE THE TENT.

Date.	Untrimmed.		Trimmed.	
July 19	1 lb.	10 ozs.		12 ozs.
" 27	15 lbs.	10 "	9 lbs.	10 "
Aug. 4	2 "		1 "	4 "
" 11	43 "		30 "	12 "
" 17	194 "	14 "	107 "	13 "
" 23	42 "	9 "	24 "	11 "
" 26	73 "	14 "	36 "	12 "
Sept. 5	34 "	5 "	20 "	10 "
" 13	45 "		19 "	
" 15	16 "	12 "	10 "	3 "
Total	469 lbs.	10 ozs.	261 lbs.	7 ozs.

The above figures show the total weight of trimmed cauliflower to have been sixty per cent greater under the tent than outside. The proportionate net weight of trimmed to untrimmed cauliflower was fifty-six per cent. in that grown outside and sixty-four per cent. in that grown inside, which indicates a relatively better development of heads. Whether this increase in yield would be sufficient to warrant the expense of providing shade, each grower would need to determine for himself.

Our experience indicates that it is possible to grow cauliflower under the tent in weather when it is almost impossible to secure it outside.

Young cauliflower plants were set August 7 in the places where mature heads had been harvested, but nearly all of these plants rotted off close to the ground, both under the tent and outside. Waste leaves from the previous crop had been allowed to lie on the ground, which doubtless contributed to this trouble.

The following readings, taken at various times throughout the season, show the comparative air temperatures under the tent and outside, the thermometers being hung about four feet from the ground in each case:

Date.	Time.	Temperature inside.	Temperature outside.
June 16	8:45	90°	82°
" 17	10:30	84°	78°
" 24	11:30	78°	76°
" 24	2:15	85°	84°
" 26	11:30	90°	84°
" 27	10:15	68°	65°
" 27	11:30	82°	73°
July 1	11:00	88°	78°
" 3	9:30	74°	72°
" 5	10:30	77°	74°
" 6	1:30	87°	83°
" 6	5:00	75°	72°
" 8	9:45	85°	82°
" 10	8:45	95°	94°

Date.	Time.	Temperature inside.	Temperature outside.
“ 10	11:00	98°	91°
“ 10	3:15	92°	89°
“ 11	10:00	95°	90°
“ 12	8:30	88°	87°
“ 14	10:00	88°	82°
“ 17	9:30	76°	*77°
“ 18	11:15	101°	95°
“ 19	1:30	96°	92°
“ 20	10:00	93°	87°
“ 21	8:30	82°	74°
“ 24	11:15	74°	73°
“ 25	10:30	90°	84°
“ 25	2:30	87°	82°
“ 26	8:45	83°	78°
“ 27	9:15	88°	83°
“ 28	2:15	90°	87°
“ 29	9:30	73°	*74°
“ 30	8:30	86°	88°
“ 31	1:45	78°	76°
Aug. 2	10:30	85°	80°
“ 2	4:30	78°	78°
“ 3	2:15	88°	84°
“ 4	10:00	90°	83°
“ 7	3:00	93°	91°
“ 8	4:30	81°	79°
“1 1	1:00	91°	86°
Average		85.55°	81.675°

These figures show the average temperature during the day to have been nearly 4° warmer inside the tent than outside. The greatest difference observed at any one reading was that taken at 11:00 A. M. July 1, when the inside temperature was 10° higher than that outside.

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*Cloudy.

DIVISION OF ANIMAL HUSBANDRY.

The work of this Division will be prepared for publication and issued in bulletins and the Report of the coming year.

DIVISION OF CHEMISTRY.

REPORT OF THE DIVISION OF CHEMISTRY.

B. L. HARTWELL, ASSOCIATE CHEMIST.

The principal analytical work, aside from the regular inspections of fertilizers and feeding-stuffs, has been in connection with the determination of the ash constituents of plants grown in soil to which different relative amounts of soda and potash had been applied. This work has progressed from time to time during a number of years as successive crops have been obtained, but it was only through the financial assistance of the Bureau of Soils of the U. S. Department of Agriculture that the ash analyses which it seemed desirable to make at the present time were completed. All of the analytical work thus far done in connection with this problem during a number of years has been embodied in an article which follows.

Considerable analytical work has been done for the other divisions of the Station, which will be published by the divisions whenever the time is opportune.

A large number of nitrogen and moisture determinations have been made during the past year on crops which have accumulated from a pot experiment which has been continued for a number of years to ascertain the relative availability of nitrogen in different nitrogenous manures.

POT AND WATER-CULTURE EXPERIMENTS.

The Bureau of Soils has continued at this Station the trial of its method of ascertaining soil deficiencies by the growth of wheat in small, paraffined wire pots. In order to compare the results obtained by this method with those secured in actual field practice, fifteen soil tests have been begun in different parts of the State upon soils representing a number of different types. Bags of these soils were sent to the Station for pot-cultures, using the same kinds and applications of manurial substances as in the field. In addition to the cultures in the small, paraffined baskets, a number of the soils are also being tested under similar conditions at the glasshouse in eight-inch Wagner pots. The endeavor will be made to grow crops to maturity in these latter pots, as in the field, whereas in the small pots no attempt is made to grow the wheat more than for about three weeks.

Pot experiments are also in progress to ascertain the amount of nitrogen which can be gathered from the air during the growth of certain legumes in a light soil. Other minor pot experiments are also in progress.

Experiments upon the growth of plants by means of water-culture were continued with the opening of the spring season, an expert having been detailed from the Bureau of Soils to aid in this work. The principal work has been in connection with the question whether or not sodium salts cause an increased growth when there is a limited supply of potash. It has been shown repeatedly in the field that there is an increased growth when sodium salts are added to a limited supply of potash, and the analytical data furnish much circumstantial evidence that the sodium acted physiologically. In order to ascertain by other and more positive means if this increase is due to a direct or an indirect action of the sodium salts, similar experiments by way of sand and water-culture seemed necessary.

In addition to the research work mentioned above, the chemical division has collected and analyzed a large number of samples of commercial fertilizers and feeding-stuffs, the results of which appear in the Station Bulletins.

MISCELLANEOUS ANALYSES.

(Other than those which will be published in connection with special articles).

B. L. HARTWELL, M. STEEL, AND J. P. GRAY.

GROUND LIMESTONE (CARBONATE OF LIME).

From the Mitchell Lime Co., Mitchell, Indiana.

	Per cent.
Calcium oxid	49.26
Magnesium oxid	2.04

This finely ground, unburned limestone is especially adapted to use on sandy soils where the more caustic, slaked, and hydrated lime might exert a temporary injurious action if used in large quantities. If the price is high and the distance of transportation is great it may however be advisable to use the slaked lime in small amounts instead of the carbonate of lime, even on sandy soils.

HYDRATED LIME.

From the Rockland-Rockport Lime Co., Rockland, Maine.

	Per cent.
Calcium oxid	61.37
Magnesium oxid	2.17

This lime is slaked by means of steam and is then bolted, hence it is in an extremely fine condition. When first prepared it is chemically the same as water-slaked lime and both are very efficient on heavy clay and acid muck soils. Air-slaked lime contains a mixture of water-slaked lime and carbonate of lime. Hydrated and water-slaked lime change to carbonate of lime after long exposures to the air.

SLAKED LIME.

	Per cent.
Calcium oxid	68.14

LIME-KILN ASHES.

From Harris Lime-kilns, Lime Rock, R. I.

	Per cent.
Potassium oxid	1.81
Calcium oxid	45.50

The composition of lime-kiln ashes is likely to vary considerably, according to how much the ashes have been exposed to the weather and the consequent amount of water and carbon dioxid contained in them.

MURIATE OF POTASH.

	Per cent.		
	I.	II.	III.
Potassium oxid	60.08	48.67	49.69

No. I. is a *high-grade* muriate of potash bought for special experimental work.

I. "HIGH GRADE" SULFATE OF POTASH.
II. POTASSIUM CARBONATE.

	Per cent.	
	I.	II.
Potassium oxid	51.56	67.65

I. NITRATE OF SODA.
II. SULFATE OF AMMONIA.
III. DRIED BLOOD.

	Per cent.		
	I.	II.	III.
Nitrogen	16.10	20.96	12.11

I. GROUND "ACID FISH."
II. TANKAGE.

	Per cent.	
	I.	II.
Nitrogen	9.42	6.81

The ground "Acid Fish" is the waste menhaden fish from the oil factories which has had a small amount of oil of vitriol (sulfuric acid) sprinkled over it to prevent its decomposition.

I. FINELY GROUND BONE.
II. DISSOLVED BONE.

	Per cent.	
	I.	II.
Nitrogen	2.54	1.74
Phosphoric acid	20.47	14.77

The dissolved bone is finely ground bone which has been treated with considerable oil of vitriol (sulfuric acid) in order to render most of the phosphoric acid soluble in water.

GUANO.

From Coe-Mortimer Co., New York.

I. LOBOS GRADE.
II. CHINCHA GRADE.

	Per cent.	
	I.	II.
Nitrogen	3.02	7.76
Phosphoric acid	19.71	9.56
Potassium oxid (acid soluble)	4.08	2.21

Guano, which disappeared from the market for several years, is now to be had again. It is an efficient manure, but as good results can probably be secured with mixtures of acid phosphate, bone meal, the German potash salts, and nitrate of soda; hence, which should be used depends solely upon the relative prices of the guano and a mixture having the same composition.

I. ACID PHOSPHATE.
II. BASIC SLAG MEAL.

	Per cent.	
	I.	II.
Phosphoric acid	14.01	17.29

The phosphoric acid of the basic slag meal is not soluble in water, but yet it is highly efficient in plant production, the slag meal being nearly as good as acid phosphate. On very acid soils and with plants injured by acidity it may act even better than acid phosphate. It, like acid phosphate, contains neither nitrogen nor potash.

I. CORN MEAL.
II. MIXED FEED.

	Per cent.	
	I.	II.
Water	13.82	.....
Protein	8.50	16.31

CONCERNING THE FUNCTIONS OF SODIUM SALTS.

H. J. WHEELER AND B. L. HARTWELL,

WITH THE ASSISTANCE OF

J. W. KELLOGG AND MATTHEW STEEL.*

The field experiments which have served as a basis for the study of the functions of the sodium salts were begun in the year 1894 and have been continued to date. The original plan was to see at the outset if practical advantage would accrue from the use of sodium salts as manures in the presence of both limited and large supplies of potassium. Having observed in the field great advantage with certain varieties of plants from the use of sodium salts in the presence of small quantities of potassium salts, and even in some cases when large amounts of the latter were employed, it seemed necessary to conduct both pot and water-culture experiments in order to eliminate certain factors which existed in the field work. Special reference is made to the indirect manurial action of sodium salts by virtue of the liberation of essential food elements from the soil itself. The influence of osmotic pressure, the chemical reaction of the medium in which the plants are grown, and other complex features only admit of satisfactory study by the method of water culture. In addition, it appeared desirable to resort to plant analysis in order to determine if more sodium had actually entered the plant, or simply more potassium in consequence of applying sodium salts and also, whether evidence would be afforded that the sodium had been of benefit by increasing the amount of calcium, magnesium, or phosphoric acid at the disposal of the plants.

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*Messrs. Kellogg and Steel, of the Bureau of Soils, U. S. Dept. Agriculture, completed the analytical work, though a part of it had already been done by Mr. Kellogg while still in the employ of the Experiment Station. A large number of analyses had been made previously by Doctor Hartwell.

In preparation for this latter work some plants were saved for analysis in the year 1898, and still more in the year which followed. Likewise in the years 1901 and 1905 samples of a number of varieties of plants were saved from the crops grown in the field experiments. From time to time, as opportunity afforded itself, the analysis of the samples was taken up, but the means at disposal often necessitated the relinquishment of the work for long periods of time. While these conditions still prevailed, application was made to the U. S. Department of Agriculture for aid in carrying forward the work. As a result, the Bureau of Soils arranged for temporary assistance in obtaining analytical data, and it is on account of this assistance that it is possible to present to the public at this time the large volume of results which follow.

It had been shown in earlier times, and had been recently demonstrated by Smets and Schreiber* in Belgium, as well as by others elsewhere, that sodium salts were highly beneficial to certain plants under given conditions of field culture. Nevertheless, it appeared highly desirable to see if there would seem to be reason for assuming, from our own results, whether sodium had acted directly or indirectly, and if probable physiological functions were to be ascribed to it when but small or insufficient amounts of potassium were present.

With the hope of making a clearer presentation of the subject, the analytical data will be presented under three distinct headings. In order, however, that the analyses may be studied in their entirety, if desired, they have all been grouped in an appendix to this article.

Owing to the large amount of work and the expense involved, it was found necessary in many cases to abbreviate the chemical work more than might be deemed advisable. It is believed, however, that valuable and conclusive light is thrown by the results upon a number of points of both scientific and practical value.

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*Recherches sur les Engrais Potassiques et Sodiques, Maaseyck, 1896.

THE INFLUENCE OF SODIUM SALTS UPON THE REMOVAL FROM THE SOIL OF NITROGEN AND PHOSPHORIC ACID.*

In order to make the discussion of this question better understood, it seems desirable to refer briefly to some of the observations on record which bear upon this question.

Birner and Lucanus* assert that sodium sulfate favors the passage of phosphoric acid into the plant, but that it lowers the per cent. of calcium taken up; also that upon employing potassium chlorid the ash and dry matter of the plants were rendered richer in magnesium and potassium, but poorer in calcium, sulfur, and phosphorus. They further add that sodium chlorid causes calcium, sulfur, and phosphorus to be taken up even more slowly, yet at the same time the percentages of magnesium and potassium were increased in both ash and dry matter.

Griffiths† says that in calcareous soils the sodium carbonate formed therein, in consequence of the application of sodium chlorid, acts as a solvent of phosphoric acid.

Müntz and Girard‡ are of the opinion that if sodium chlorid exerts a solvent action upon soil phosphates and upon the potassium in silicate combinations, this action must be extremely limited.

Pagnoul § conducted some experiments with potatoes, which were followed the second year by oats. He employed white silica as a medium in which to grow his plants, and this, upon analysis, was found to contain the following:

	Per cent.
Calcium carbonate	.00495
Phosphoric acid	.00232
Potassium oxid	.00658
Iron and aluminum oxids	.11000

In all cases like amounts of nitrogen and phosphorus were present in the manures. To one series of pots calcium salts were added, to another sodium salts, and to a third potassium salts. In the first series the phosphorus was supplied in solution, in superphosphate of lime, and in the other two cases in sodium and potassium phosphate, respectively. The percentage of phosphoric acid in the potatoes was not determined. Below are given the data in relation to the oats:

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*Landw. Vers. Stat. 8 (1866), p. 140.

†A Treatise on Manures, London (1889), p. 255.

‡Les Engrais III (1891), p. 152.

§Ann. Agron. 20 (1894), p. 467–479.

	Receiving potassium salts.	Receiving sodium salts.	Receiving calcium salts.
	Grams.	*Grams.*	*Grams.*
Total weights of plants	716.2	508.8	311.7
Relative weights	100	71	43
Constituents per 100 parts of dry matter.			
Potassium oxid	7.001	1.192	0.934
Sodium oxid	0.000	4.585	0.920
Calcium oxid	0.634	0.682	1.956
Phosphoric acid	3.043	1.983	1.300
Nitrogen	4.320	4.620	4.480

Pagnoul points out that the crop increased with the increase in total percentage of alkalis, and he further adds that the increase in the yield was almost exactly in accord with the increase in the percentage of phosphoric acid.

In this instance the influence of the calcium, sodium, and potassium was exerted upon the materials which had been applied in solution to the nearly pure silica, and hence it does not deal with the effect of these substances upon the natural phosphatic constituents of ordinary soils.

Dehérain* has called attention to the fact that in a certain section of France where no after-effect of an acid phosphate was noticeable, subsequent liming apparently rendered the phosphoric acid available to plants. Similarly at this Station a soil greatly benefited by applications of dissolved bone-black appeared not to require it for several years subsequent to liming. Other experiments at this Station show the most striking benefit from liming, in connection with applications of roasted Redondite.* This beneficial effect is believed to be due to the basic action of the lime in the acid soil. If such is the true explanation it might be expected that sodium carbonate, a highly alkaline compound, would, as has been claimed, act similarly upon certain mineral phosphates, and that it would also exert a solvent and decomposing action upon the humus compounds which have a considerable phosphorus content.

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*Traité de Chimie Agricole, Paris (1892), p. 525.

It is well known that the presence of sodium chlorid in certain solutions increases their solvent action upon various chemical compounds; hence, it would not be surprising if, as stated by Peligot,† it should exert such an action upon some of the phosphates. It is probably, therefore, not necessary to its influence, as a solvent of certain kinds of phosphorus compounds, that it be changed into sodium carbonate in the soil by reacting upon carbonate of lime, as suggested by Griffiths.‡

It is often a most difficult matter to decide, solely by the chemical examination of a plant, whether deficiencies or excesses of certain ingredients found therein are really indicative of such deficiencies or excesses in the soil in which it was grown. This is well illustrated by the common experience in determining the percentage of nitrogen in very small and immature plants, grown where nitrogen is deficient, since they are almost invariably found to be richer in nitrogen than larger plants which have been supplied with an abundance of nitrogen in readily assimilable combinations. It is known equally well that certain plants remove far more potassium from the soil than they seem to need, a point that has been abundantly established by the Rothamsted investigations and by chemists in many other countries.§

In the case of phosphoric acid, particularly with the cereals, no such excessive overloading of the plant seems to occur as has been observed in connection with root crops, in their removal of potassium.

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*Buls. Nos. 114 and 118, R. I. Agr. Expt. Station.

†Compt. Rend. Acad. Sci. (Paris) (1871), p. 1078.

‡Treatise on Manures, (London) (1899), p. 255.

§Jordan and Jenter, Bul. No. 192, N. Y. Agr. Exp. Station (Geneva), 1900, p. 349, show that pea plants took up in one case ten times as much potash as in another.

Hartwell and Kellogg,* in the analysis of crops grown at the Rhode Island Station, found that the flat turnip exhibited striking increases of phosphoric acid with the increased yields. In the case of oats and certain other varieties of plants grown under the same conditions, the analytical data were often conflicting; or in other words, the analysis of these plants often failed to indicate truly and surely the apparent relative availability of the soil phosphates. It is stated by A. D. Hall† that "The proportion of phosphoric acid and of potash in the ash of any given plant varies with the amount of these substances available in the soil, as measured by the response of the crops to phosphatic or potassic manures, respectively.

"The extent of the variation due to this cause is limited, and is often no greater than the variations due to season, or than the other variations induced by differences in the supply of non-essential ash constituents—soda, lime, etc.

"The fluctuations in the composition of the ash are reduced to a minimum in the case of organs of plants, which, like the grain of cereals, or the tubers of potatoes, are manufactured by the plant from material previously assimilated.

"The composition of the ash of the cereals is less affected by changes in the composition of the soil than is that of the root crops like swedes and mangels.

"The composition of the ash of mangels grown without manure on a particular soil gives a valuable indication of the requirements of the soil for potash manuring. Similarly the phosphoric acid requirements are well indicated by the composition of the ash of unmanured swedes."

It appears from what has been cited that, if the other factors are identical, certain of the root crops may show by the composition of their ash, in agreement with the yields, whether or not a deficiency of phosphoric acid exists, and also what influence upon its availability has been exerted by the application of specific substances.

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*Eighteenth Ann. Rpt., R. I. Agr. Expt. Sta. (1904–05), p. 253.

†Jour. of Agr. Sci. 1 (1905), p. 88.

The general presentation of the foregoing matter has, as previously suggested, seemed to be a necessary prerequisite to an intelligible discussion of certain experimental data secured at this Station. Special reference is made in this connection to the yields and to the analysis of certain crops grown in connection with various amounts of sodium and potassium salts.

The complete details of the plan of this experiment and of the crop yields have already been presented elsewhere.*

The opposite diagram shows the plan of the field and the general scheme for the application of the sodium and potassium salts. The two series of plats indicated as "limed 1902" received no second application. The other two series as shown in the diagram were limed in 1894 when the experiment was begun,† and again in 1896 and 1902.

All of the plats were manured in an identical manner with magnesium sulfate (Epsom salts), and with phosphatic and nitrogenous manures. Nitrate of soda and nitrate of potash were not employed as sources of nitrogen, owing to the fact that they would also have supplied sodium and potassium. In 1905 ammonium nitrate was employed for the first time to supply a part of the nitrogen. In the earlier years the nitrogen was introduced entirely in dried blood, bone, or tankage, or in mixtures of two or more of these substances.

Until 1905 the quantities of potassium carbonate were made such, each year, that the "full ration" would neutralize the same amount of acid as the "full ration" of sodium carbonate. The amounts of muriate of potash and of sodium chlorid (common salt) have been so regulated, when applied, as to furnish the same quantities of potassium and sodium as the respective carbonates.

In the years 1902, 1903, and 1904 the plats were all devoted to grass, and no applications were made to any of them, with the exception of tankage, which was applied to all at a uniform rate.

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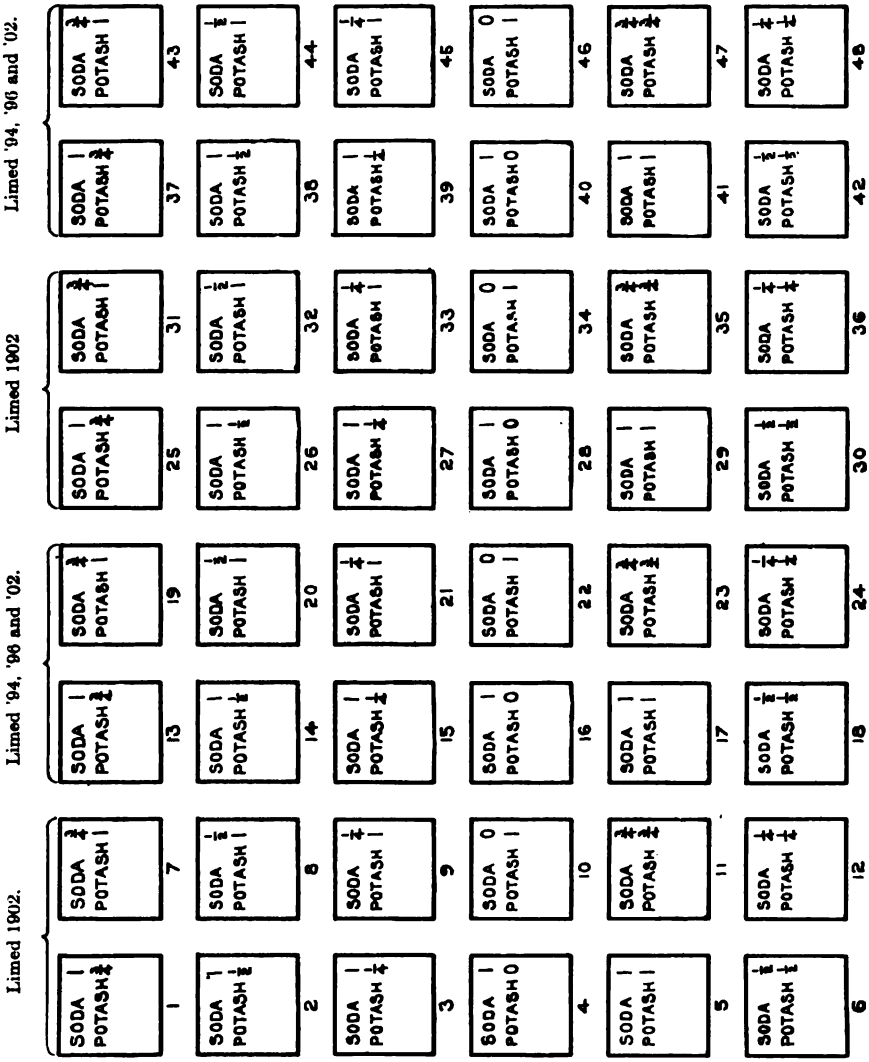
*Seventh Ann. Rpt. (1894), pp. 168–182; Eighth Ann. Rpt. (1895), pp. 215–231; Ninth Ann. Rpt. (1896), pp. 221–241; Tenth Ann. Rpt. (1897), pp. 226–240; Eleventh Ann. Rpt. (1898), pp. 137–143; Bul. No. 104, Feb., 1905; and Bul. No. 106, May, 1905.

†In Bulletin No. 104, p. 49, mention of the fact that plats 13 to 24 and 37 to 48 were limed again in 1896 was omitted. Also in Bulletin No. 106 the plats said to have been limed twice. including and subsequent to the year 1902, had actually been limed three times.

Plan of Field. Experiment begun in 1894.



Plats 1–24, chlorids, and 25–48, carbonates.

In certain of the years prior to 1902, and also in the year 1905, some of the crops were saved for analysis with the hope that the analytical data might throw some light upon the probable action of the sodium salts. It now remains to consider these results and to discuss their probable significance.

Results with Golden Millet in 1898.

In 1898 each of the forty-eight plats received the following applications:

Pounds per acre.	
1,020	dried blood.
600	dissolved bone-black.
480	floats.
420	magnesium sulfate (Epsom salts).

The full rations of the respective potassium and sodium salts were as follows:

Pounds per acre.	
360.0	potassium carbonate.
247.8	sodium carbonate.
405.0	muriate of potash (manure salt).
278.4	sodium chlorid (common salt, coarse-fine).

All of the materials enumerated above were spread upon the surface after plowing, and were then thoroughly harrowed into the soil.* Below are given the percentages of phosphoric acid in the golden millet from plats Nos. 36 and 27:

Plat No.		Yield of golden millet, green.	Phosphoric acid in dry matter.
		Pounds.	*Per cent.*
36	Carbonates, unlimed, ¼ soda, ¼ potash..	132.1	.63
27	" " 1 soda, ¼ potash..	102.1	.79

In this instance the smaller weight of crop was accompanied by the greater percentage of phosphoric acid and the greater application of sodium carbonate. The smaller yield where the larger amount of sodium carbonate was employed may have been due to its lessening the acidity of the soil and thus producing an unfavorable condition for the growth of the millet. The ground for this view is the fact that in twenty-four comparisons upon limed and unlimed acid soil made in the year 1899 the yield of golden millet was found in every case to have been reduced by liming.*

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*For full details of the yields see Eleventh Ann. Rpt., R. I. Agr. Expt. Sta. (1898), p. 141.

Results with Radish, Flat Turnip, Mangel-Wurzel, Carrot, and Chicory, in 1899.

In 1899 all of the forty-eight plats were manured at equal rates with the following materials:

Pounds per acre.	
1,020	dried blood.
600	dissolved bone-black.
480	floats (finely ground phosphate rock).
420	magnesium sulfate (Epsom salts).

The full rations of the potassium and sodium salts were as follows:

Pounds per acre.	
300.0	potassium carbonate.
331.8	muriate of potash (manure salt).
202.2	sodium carbonate.
231.6	sodium chlorid (common salt, coarse-fine).

The scheme of application of the manures was the same as in 1898. The analyses of the crops show the results with a quarter ration each of the potassium and sodium salts, in contrast with those secured with a quarter ration of potassium salt supplemented with a full ration of sodium salt. These comparisons are made in limed and unlimed series with both carbonates and chlorids; likewise the data show the results under the same conditions with half rations of each salt used together, contrasted with a half ration of potassium salt supplemented by a full ration of sodium salt.

Below are shown the yields of certain varieties of plants, together with the percentages of phosphoric acid and nitrogen actually contained in the dry matter:

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*Bul. 104, R. I. Agr. Expt. Sta., Feb., 1905, p. 87.

Radish, White Strasburg, Roots, 1899.

Plat No.	Special Manures Applied.	Yields,* green, pounds.	Per cent. in dry matter.	
			Phosphoric acid, P_2O_5.	Nitrogen.
12	Chlorids, unlimed; ¼ soda, ¼ potash	547	1.02	3.42
3	Chlorids, unlimed; 1 soda, ¼ potash	709	1.13	3.68
24	Chlorids, limed; ¼ soda, ¼ potash	432	0.89	3.53
15	Chlorids, limed; 1 soda, ¼ potash	685	0.98	3.54
36	Carbonates, unlimed; ¼ soda, ¼ potash	547	0.99	3.33
27	Carbonates, unlimed; 1 soda, ¼ potash	722	1.13	3.74
48	Carbonates, limed; ¼ soda, ¼ potash	432	0.96	3.77
39	Carbonates, limed; 1 soda, ¼ potash	540	1.08	3.60
6	Chlorids, unlimed; ½ soda, ½ potash	797	0.98	3.19
2	Chlorids, unlimed; 1 soda, ½ potash	834	1.02	3.31
18	Chlorids, limed; ½ soda, ½ potash	662	0.84	3.74
14	Chlorids, limed; 1 soda, ½ potash	766	0.90	3.71
30	Carbonates, unlimed; ½ soda, ½ potash	776	1.05	3.47
26	Carbonates, unlimed; 1 soda, ½ potash	817	1.13	3.80
42	Carbonates, limed; ½ soda, ½ potash	621	1.05	3.59
38	Carbonates, limed; 1 soda, ½ potash	662	1.10	3.85

*Yields per one-sixtieth acre.

It will be observed, in the case of the radish, that in every one of the four instances where comparisons are possible there was a smaller percentage of phosphoric acid in the dry matter of the root where only a quarter ration of each salt was used than where the extra three-quarter ration of the sodium salt was added. Similarly in every one of the four cases where a combination of a half ration each of sodium and of potassium salt was employed the percentage of phosphoric acid in the dry matter was less than where an extra half ration of the sodium salt was present. Comparing the results with carbonates and chlorids, it is seen that the percentages of phosphoric acid were identical in one case, in a second the chlorid gave a higher percentage, and in the other six instances the percentages were lower in the case of the chlorids than where the carbonates were used.

Liming lowered the percentage of phosphoric acid in the crop in all but one of the eight cases, and in that instance the results were identical. Notwithstanding that liming seems to aid in placing at the disposal of plants the phosphoric acid which is present in the soil in certain combinations with iron, it is well understood that the presence of large amounts of carbonate of lime in the soil tends to bring about a reversion or fixation of the phosphoric acid applied in superphosphates. This latter effect, and the fact that the slaked lime was applied five and three years before, in consequence of which its action upon the phosphorus compounds of the soil had practically ceased by virtue of its changed chemical character, account readily for the lesser percentage of phosphoric acid in the radish roots from the limed plats.

The increase in the percentage of phosphoric acid in consequence of the employment of the carbonates, in contrast to the result with the chlorids, may have been due to the solvent action of the carbonates either upon iron, and aluminum phosphates, or upon the phosphorus of the humus compounds.

In view of the fact that increases in the amounts of sodium salts have been shown by these results to unquestionably increase the amount of phosphorus in the plants, the important question arises whether the extra phosphorus was needed in connection with the physiological processes of the plant, or if it was merely an unnecessary surplus. If the extra phosphorus were necessary to the physiological processes, it would hardly be expected that equally large crops would be produced with smaller percentages. Viewed in this light, the results furnish further interesting evidence. For example, in three instances the percentages of phosphoric acid in the dry matter were 1.13, the maximum amount, and the corresponding yields of radishes were 709, 722, and 817 pounds; again, there was a yield of 797 pounds with a phosphoric acid percentage of .98. one of 834 pounds with but 1.02 per cent. of phosphoric acid, one of 766 pounds with a phosphoric acid content of but .90 per cent. and one of 776 pounds with a percentage of 1.05 of phosphoric acid. In so far, therefore, as these results afford a basis for conclusions, there seems to be considerable evidence that the extra phosphoric acid which the plants in some cases appropriated may not have been actually required. If this is the correct interpretation to place upon the evidence, it would appear as if the increased yields of radishes were very likely due, not to the phosphoric acid, but to some direct beneficial influence of the sodium salt. A yield of 709 pounds in this case was equivalent to 42,540 pounds per acre, showing that the crops were of a normal size.

At this point it will be well to consider certain results with the English, or flat turnip.

Turnip, Flat, Roots, 1899.

Plat No.	Special Manures Applied.	Yields, green, pounds.	Per cent. in dry matter.	
			Phosphoric acid.	Nitrogen.
24	Chlorids, limed; ¼ soda, ¼ potash................	214	0.98	*
15	Chlorids, limed; 1 soda, ¼ potash................	293	1.26	*
36	Carbonates, unlimed; ¼ soda, ¼ potash...........	149	1.00	4.19
27	Carbonates, unlimed; 1 soda, ¼ potash...........	212	0.89	3.92

*Not determined.

In this instance the data are too few to throw any light upon the relative action of the carbonates and chlorids upon the amount of phosphorus removed by the plants. The same is also true concerning the action of lime. The higher percentage of nitrogen in this instance coincided with the higher percentage of phosphoric acid and the smaller yield.

It is significant to observe that in both instances there were considerably greater yields where the extra amount of sodium salt was added than where only a quarter ration each of sodium and potassium salts was applied. Nevertheless in one instance the percentage of phosphoric acid increased with the increase in the crop, and in the other case the percentage was .11 less in the larger crop than in the smaller. Such evidence as is afforded is therefore to the effect that the extra sodium salt was positively helpful in increasing the crops, and there is no positive evidence that this increase was due to indirect action in liberating phosphoric acid.

Below are given a few data secured with the Norbiton giant beet (Mangel-wurzel) in 1899.

Beet, Norbiton Giant, Roots, 1899..

Plat No.	Special Manures Applied.	Yields, green, pounds.	Per cent. in dry matter.	
			Phosphoric acid.	Nitrogen.
24	Chlorids, limed; ¼ soda, ¼ potash	421	0.24	1.63
15	Chlorids, limed; 1 soda, ¼ potash	682	0.32	1.75
48	Carbonates, limed; ¼ soda, ¼ potash	299	0.37	2.23
39	Carbonates, limed; 1 soda, ¼ potash	601	0.39	2.20

In both of the foregoing instances the percentages of phosphoric acid and of nitrogen in the crop were greater where the carbonates were employed than where the chlorids were used. In respect to the phosphoric acid the results are in agreement with those obtained with the radish in the same year.

In the chlorid series the nitrogen and phosphoric acid were both increased by the extra sodium, but in the carbonate series no such relationship existed.

These results also agree with those secured in connection with the radish in showing an increase in the phosphoric acid percentage in the dry-matter when the quarter ration each of the two salts was supplemented by a three-quarter ration of the respective sodium salt. At first thought one might be led to conclude that the remarkable benefit from the sodium salt was attributable to its having rendered more phosphoric acid assimilable, yet in view of the fact that the crop of 299 pounds contained a percentage of 0.37 of phosphoric acid and the one of 421 pounds contained a percentage of but 0.24 of phosphoric acid, this does not seem probable. Furthermore, in view of the fact that the crop of 601 pounds showed a percentage of 0.39 of phosphoric acid as compared with 0.32 in the instance of the crop of 682 pounds, it is difficult to accept such an explanation. These data indicate, rather, that the sodium salt was of some other benefit to the plant.

So far as concerns the nitrogen, the percentage was greater in one case and smaller in the other, when the larger crops were secured.

Results with Carrots in 1899.

The following data were secured in connection with the carrot in 1899:

Carrot, Roots, 1899.

Plat No.	Special Manures Applied.	Yields, green, pounds.	Per cent. in dry matter.	
			Phosphoric acid.	Nitrogen.
24	Chlorids, limed; ¼ soda, ¼ potash	343	1.03	2.58
15	Chlorids, limed; 1 soda, ¼ potash	483	1.20	2.73
48	Carbonates, limed; ¼ soda, ¼ potash	373	1.07	3.02
39	Carbonates, limed; 1 soda, ¼ potash	483	1.09	2.93

It will be observed that the use of an extra amount of sodium salt was accompanied by increased crops in both instances. The results with the carrot are conflicting in so far as concerns the respective influence of the carbonates and chlorids upon the phosphoric acid content of the roots, but in the case of the nitrogen the percentage was higher in both instances when the carbonates were used than when the corresponding chlorids were employed.

In both cases the results agree in showing a greater percentage of phosphoric acid in the dry matter when an extra three-quarter ration of the sodium salt was added.

In view of the difference in yield of 110 pounds in the case of the crops from plats Nos. 39 and 48 when the difference in the percentage of phosphoric acid in the dry matter amounted to but 0.02, it does not seem justifiable to conclude that the soda had increased the crop by virtue of aiding in rendering the phosphoric acid available. Furthermore, if the percentage of 1.20 of phosphoric acid were necessary to the production of the 483 pounds of crop in the case of plat No. 15, it would not have been possible to have produced the crop of 483 pounds in the case of plat No. 39 with only 1.09 per cent. of phosphoric acid present in the dry matter of the plants. To be sure, the chlorin in the one case and the carbon dioxid in the other might be mentioned as other factors which would militate against such a line of argument, but nothing of this kind can be advanced as an objection to the argument employed in connection with plats Nos. 39 and 48.

Where the extra amount of sodium salt was applied and both the crop yields and the percentages of phosphoric acid were increased, the nitrogen percentages in the two cases were contradictory.

Results with Chicory Roots.

Below are given certain results obtained with chicory roots in 1899:

Chicory, Roots, 1899.

Plat No.	Special Manures Applied.	Yields, green, pounds.	Per cent. in dry matter.	
			Phosphoric acid.	Nitrogen.
24	Chlorids, limed; ¼ soda, ¼ potash................	200	0.49	*
15	Chlorids, limed; 1 soda, ¼ potash................	189	0.48	*
48	Carbonates, limed; ¼ soda, ¼ potash..............	234	0.56	*
39	Carbonates, limed; 1 soda, ¼ potash..............	205	0.59	*

*Not determined.

The chicory affords a striking contrast to the radish, turnip, beet, and carrot on account of the yields having been less where the extra three-quarter ration of sodium salt was used than where only a quarter ration each of the sodium and potassium salts was employed.

The results are in full agreement with those with the radish and beet in showing higher percentages of phosphoric acid when the carbonates were used than when the chlorids were employed.

The differences in the phosphoric acid percentages in the two cases, as influenced by the extra applications of sodium, are not only slight, but also contradictory.

Results with Several Varieties of Plants in 1901.

In 1900 Indian corn was grown upon all of the plats, but no attempt was made to save any of the material for analysis.

All of the forty-eight plats were manured that season at the same rates and with the same kinds of manures as in the previous year (see p. 195), excepting that the full rations of the sodium and potassium salts were as follows:

Pounds per acre.	
280.8	muriate of potash (manure salt).
240.0	potassium carbonate.
182.4	sodium chlorid (common salt).
163.2	sodium carbonate (soda ash).

The various plats received the same rations and fractions of rations of the respective salts as in previous years.

In view of the fact that certain analytical data had already shown in the case of the crops of 1899, that the sodium had probably facilitated the taking up of phosphoric acid and possibly of magnesia, it was decided to increase the quantities of phosphatic and magnesian manures applied to all of the plats. In consequence, the quantities of manures used in 1901 were made as follows:

Pounds per acre.	
1,296	acid phosphate.
480	floats.
600	magnesium sulfate.
1,020	dried blood.

Below are given the full rations of the respective sodium and potassium salts which were employed:

Pounds per acre.	
241.2	muriate of potash (manure salt).
210.0	potassium carbonate.
157.8	sodium chlorid (common salt).
142.2	sodium carbonate (soda ash).

The full rations and fractions of rations of the respective salts were applied to the same plats as in the preceding years.

Below are given the results secured with several of the varieties of plants which were grown upon the plats in 1901.

Radish, White Strasburg, Roots, 1901.

Plat No.	Special Manures Applied.	Yields, green, pounds.	Per cent. in dry matter.	
			Phosphoric acid.	Nitrogen.
22	Chlorids, limed; 0 soda, 1 potash	248	1.03	*
20	Chlorids, limed; ½ soda, 1 potash	261	1.09	*
19	Chlorids, limed; ¾ soda, 1 potash	243	1.06	*
34	Carbonates, unlimed; 0 soda, 1 potash	288	1.09	*
32	Carbonates, unlimed; ½ soda, 1 potash	291	1.15	*
31	Carbonates, unlimed; ¾ soda, 1 potash	279	1.12	*
46	Carbonates, limed; 0 soda, 1 potash	228	0.92	*
44	Carbonates, limed; ½ soda, 1 potash	252	1.00	*
43	Carbonates, limed; ¾ soda, 1 potash	243	1.09	*
12	Chlorids, unlimed; ¼ soda, ¼ potash	234	1.08	3.54
3	Chlorids, unlimed; 1 soda, ¼ potash	216	1.08	3.20

*Not determined.

Comparing the results of the examination of the crops from plats Nos. 19, 20, and 22 with those of the crops of plats Nos. 43, 44, and 46, it will be seen that with one unimportant exception a greater percentage of phosphoric acid was not found where the carbonates were employed than where the chlorids had been used. In this respect the results are different from most of those secured with the radish in 1899. This may readily have been due, however, to the larger amount of superphosphate applied in 1901, and to the lesser opportunity for any phosphoric acid to come into play which might have been rendered available by the action of the carbonates either upon iron phosphate or the phosphorus of the humus compounds.

The percentages of phosphoric acid in the crop were in all three instances smaller where the full rations of the potassium salts were used than where the same were supplemented by fractional rations of the sodium salts. Nevertheless, in only one of the three cases was the percentage greater where a three-quarter ration of sodium salt was used than where but a half ration was added. In none of the cases were there more than incidental differences in yields, and certain of these were in opposite directions from those of the phosphoric acid percentages, so that no positive relationship between the yields, and the percentages of phosphoric acid is exhibited.

In the single comparison of the result when the crop was grown with a quarter ration of each salt with that where an extra three-quarter ration of the sodium salt was added, the percentages of phosphoric acid were identical and the yield was slightly less in the latter instance. In this respect the result differs greatly from those obtained in 1899, when marked increases in yield resulted from the use of the extra sodium salt. The analyses of most of the foregoing crops were made primarily to throw light upon another problem, which will be considered later.

Chicory, Roots, 1901.

Plat No.	Special Manures Applied.	Yields, green, pounds.	Per cent. in dry matter.	
			Phosphoric acid.	Nitrogen.
22	Chlorids, limed; 0 soda, 1 potash	243	0.43	*
20	Chlorids, limed; ½ soda, 1 potash	243	0.42	*
19	Chlorids, limed; ¾ soda, 1 potash	243	0.44	*
34	Carbonates, unlimed; 0 soda, 1 potash	162	0.39	0.95
32	Carbonates, unlimed; ½ soda, 1 potash	180	0.41	0.95
31	Carbonates, unlimed; ¾ soda, 1 potash	194	0.40	0.96
24	Chlorids, limed; ¼ soda, ¼ potash	194	0.43	1.03
15	Chlorids, limed; 1 soda, ¼ potash	225	0.53	1.12
48	Carbonates, limed; ¼ soda, ¼ potash	131	0.49	1.14
39	Carbonates, limed; 1 soda, ¼ potash	117	0.48	1.19
	Chicory, Tops, 1901.			
48	Carbonates, limed; ¼ soda, ¼ potash	*	0.51	*
39	Carbonates, limed; 1 soda, ¼ potash	*	0.56	*

*Not determined.

In the series embracing plats Nos. 19, 20, and 21, where the full ration of potassium salt was used, the further addition of sodium salt was not accompanied by an increased yield. In the next series (plats No. 31, 32, and 34) there was a regular increase of crop accompanying each increase in the application of sodium salt.

It will be seen that in the two limed series the yields when only a quarter ration of each salt was used were much less than when a full ration of the corresponding potassium salt was employed. In the instance of the crops from plats Nos. 39 and 48 the use of the additional three-quarter ration of the sodium salt did not increase the yield, though an apparent increase resulted in the limed chlorid series under the same conditions.

There was a lack of positive evidence on the part of the roots that the presence of extra amounts of sodium salts had increased the percentages of phosphoric acid in the plants. Only a mere suggestion to this effect was obtained in the single instance where the tops were examined, in which case there was a slightly greater percentage of phosphoric acid in those grown with the extra amount of the sodium salt.

There is also a suggestion that liming may have raised the percentages of nitrogen in the crop but even this is uncertain in view of the fact that other conditions were variable in the limed and unlimed plats.

Carrot Roots, 1901.

Plat No.	Special Manures Applied.	Yields, green, pounds.	Per cent. in dry matter.	
			Phosphoric acid.	Nitrogen.
24	Chlorids, limed; ¼ soda, ¼ potash................	315	0.93	2.37
15	Chlorids, limed; 1 soda, ¼ potash................	313	0.95	1.98
48	Carbonates, limed; ¼ soda, ¼ potash.............	315	0.77	2.09
39	Carbonates, limed; 1 soda, ¼ potash.............	306	1.04	2.49
	Carrot, Tops, 1901.			
48	Carbonates, limed; ¼ soda, ¼ potash.............	*	0.70	2.87
39	Carbonates, limed; 1 soda, ¼ potash.............	*	0.80	3.08

*Not determined.

It will be seen that the percentage of phosphoric acid was greater in only one of the two instances when the carbonates were employed than when the chlorids were used.

In neither case was the crop greater when an extra three-quarter ration of the sodium salt was used than when only a quarter ration each of the potassium and sodium salt was employed.

In all three instances the percentages of phosphoric acid were greater in the case of the corps grown with the aid of additional sodium salts. It will be seen, therefore, that increased percentages of phosphoric acid resulted in the crop in the case of the carrot tops and roots without an accompanying gain in the yield of roots; in which respect the results differ from those of the year 1899, when smaller amounts of phosphates were used. It is also of interest to note that the percentages of phosphoric acid were also rather less in 1901 than they were in 1899. It is recognized that the climatic differences of the two seasons might alone account for considerable variation in the percentages of phosphoric acid; yet the fact that the increased percentages in 1901 accompanied the use of larger amounts of the sodium salts without an accompanying gain in crop still further strengthens the belief that the increased yields in 1899, resulting from the use of additional sodium salts, were probably not in consequence of the larger amount of phosphoric acid which the crop had been able to take up.

In the case of the roots the percentage of nitrogen was in one case less and in one case greater when an additional amount of sodium salt was employed, and the difference in the per cent. of nitrogen in the tops is too small to have special significance.

Results with Several Varieties of Crops in 1905.

The plats in this experimental field were devoted to grass in 1902, 1903, and 1904. In each of those years tankage was applied to all of the plats at the uniform rate of 1,200 pounds per acre. Before seeding in the spring of 1902 all of the forty-eight plats were limed at the rate of one ton per acre. It may be mentioned that in 1894 and 1896 plats 13 to 24, inclusive, and 37 to 48, inclusive, had already been limed, but that no lime had been applied to any of the other plats prior to 1902.

In 1905 the plats were plowed, and all were manured uniformly as follows:

Pounds per acre.	
1,500	dissolved bone.
1,000	dried blood.
420	magnesium sulfate.

In this season, for the first time, the idea of using amounts of sodium carbonate for the full ration which should neutralize the same amount of acid as the full ration of potassium carbonate was abandoned. This was for the reason that it was desired to make applications of potassium which would be so great that no additional amount of potassium salts would result in benefit, and it was feared that the use of the larger amounts of chlorids corresponding to the full ration of potassium carbonate and a full ration of the sodium carbonate might otherwise prove poisonous to the crop.

The full rations of the sodium and potassium salts in 1905 were therefore made as follows:

Pounds per acre.	
402.8	muriate of potash (high grade manure salt).
354.9	potassium carbonate.
200.0	sodium chlorid (common salt).
185.0	sodium carbonate (soda ash).

In addition to the usual manures, which were harrowed into the soil, an application of ammonium nitrate at the rate of 72 pounds per acre was made broadcast to all of the plats just prior to the appearance of the young plants. The object in using ammonium nitrate was to have some immediately assimilable nitrate present at the outset, in order that there might be no delay in the growth in consequence of any possible delay in the nitrification of the dried blood.

Half of each plat was devoted to flat turnips and the other half to Strasburg (white) radish.

The yields and the analytical data concerning the crops upon certain of the plats are given below. The yields are calculated to the basis of one-sixtieth of an acre, in agreement with all of the yields which have preceded.

Radish, White Strasburg, Roots, 1905.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Phosphoric acid.	Nitrogen.
12	Chlorids, limed once; ¼ soda, ¼ potash	398	1.07	3.84
3	Chlorids, limed once; 1 soda, ¼ potash	456	1.10	3.50
24	Chlorids, limed thrice; ¼ soda, ¼ potash	324	0.98	4.03
15	Chlorids, limed thrice; 1 soda, ¼ potash	438	1.08	4.11
36	Carbonates, limed once; ¼ soda, ¼ potash	372	1.15	3.76
27	Carbonates, limed once; 1 soda, ¼ potash	400	1.26	4.10
48	Carbonates, limed thrice; ¼ soda, ¼ potash	375	1.03	3.87
39	Carbonates, limed thrice; 1 soda, ¼ potash	398	1.16	3.87
11	Chlorids, limed once; ¾ soda, ¾ potash	557	1.03	3.65
1	Chlorids, limed once; 1 soda, ¾ potash	550	0.97	3.47
23	Chlorids, limed thrice; ¾ soda, ¾ potash	498	1.00	3.76
13	Chlorids, limed thrice; 1 soda, ¾ potash	547	1.05	3.88
35	Carbonates, limed once; ¾ soda, ¾ potash	553	1.11	3.65
25	Carbonates, limed once; 1 soda, ¾ potash	556	1.16	3.77
47	Carbonates, limed thrice; ¾ soda, ¾ potash,	514	1.12	3.82
37	Carbonates, limed thrice; 1 soda, ¾ potash	555	1.01	3.66

With the exception of a lower percentage of phosphoric acid in the crop from plat No. 37, as compared with the percentage in the case of the crop from plat No. 13, it will be seen that in all of the eight cases where comparisons are permissible the use of sodium carbonate and of potassium carbonate was followed by higher percentages of phosphoric acid than when the corresponding chlorids were employed. In this respect the results support the observations made in 1899. It is of interest to note that the crops were in three cases larger where the chlorids were employed than with the corresponding carbonates, even notwithstanding the greater percentages of phosphoric acid in the crops produced with the carbonates. This difference in yields appears to have been due, probably, to the fact that the radish often thrives better upon a somewhat acid soil than upon one which has been rendered neutral or alkaline. At all events, an indication is afforded that in these particular instances the amount of phosphoric acid taken up by the plant can not be considered as *the factor* in determining the size of the crop.

An examination of the results where a quarter ration each of potassium and sodium salts was applied reveals the fact that the crops were smaller in every case than where an extra three-quarter ration of the sodium salt was added; and, furthermore, the percentages of phosphoric acid in the crops increased in each instance upon the addition of the extra sodium salt. Where a three-quarter ration of each salt was supplemented by an extra quarter ration of the sodium salt the yields were materially greater in only two of the four cases, and in but one of these instances was the percentage of phosphoric acid in the crop greater than where a smaller amount of the sodium salt had been used. In fact, a three-quarter ration of the sodium salt gave such a large supply that the addition of an extra quarter ration could not be expected to exert the same effect as where the initial amount of the sodium salt was less. Another factor which would also be expected to lessen the effect of the extra amount of the sodium salt was the presence of a three-quarter ration of potassium salt.

In addition to the evidence already presented above, to the effect that the percentage of phosphoric acid in the crop was not *the factor* governing the yield under the conditions of this experiment, it will be observed that in no instance where the yields amounted to over 500 pounds was the percentage of phosphoric acid as great as in the instance of the crop upon plat No. 27, where the yield was only 400 pounds. It will be seen also that in the case of plat No. 36, with a yield of but 372 pounds, the per cent. of phosphoric acid in the crop was larger than in any instance but one, where the crop exceeded 500 pounds. This view that the per cent. of phosphoric acid in the plant was not the important factor influencing the yield is even more strongly impressed when one observes the commanding influence upon crop production exerted by the extra quantities of potassium salts, as shown by the yields given in the lower as compared with the upper part of the preceding table. If sodium can replace some of the potassium in certain functions, the reason for its benefit becomes more obvious.

It will be observed that in five of the eight cases an increase in the percentage of nitrogen accompanied the increased yields and the use of additional sodium salts, which would give some slight ground for accepting in this case the belief held at Rothamsted and at Halle that sodium is helpful by virtue of acting as a ready carrier of nitrogen to the plant. Yet when one observes that some of the highest percentages of nitrogen accompany certain low yields, the ground for such a conclusion is somewhat weakened.

Below are given the results where the effect of a full ration of potassium salt is compared with that of the same ration supplemented by a half ration of sodium salt.

Radish, White Strasburg, Roots, 1905.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Phosphoric acid.	Nitrogen.
10	Chlorids, limed once; 0 soda, 1 potash	522	1.08	3.51
8	Chlorids, limed once; ½ soda, 1 potash	542	1.06	3.52
5	Chlorids, limed once; 1 soda, 1 potash	574	1.02	3.46
22	Chlorids, limed thrice; 0 soda, 1 potash	522	1.02	3.85
20	Chlorids, limed thrice; ½ soda, 1 potash	553	1.02	3.94
34	Carbonates, limed once; 0 soda, 1 potash	548	1.17	3.60
32	Carbonates, limed once; ½ soda, 1 potash	555	1.19	3.69
46	Carbonates, limed thrice; 0 soda, 1 potash	508	1.06	3.77
41	Carbonates, limed thrice; 1 soda, 1 potash	532	1.09	3.49

It is obvious, from a glance at the yields immediately preceding these, that a three-quarter ration of potassium salt was all that the plants apparently needed in the presence of a three-quarter ration of sodium salt. In all of the four cases in this instance greater yields were obtained where the full ration of potassium salt was supplemented by a half or full ration of sodium salt than where the former alone was employed. Though these results may have been merely accidental, they appear indicative of possible benefit from the sodium salt in the presence of what would seem to have been a sufficient amount of potassium salt. That the increased yields in this particular instance were due to a greater assimilation of phosphoric acid in consequence of the presence of the sodium salts seems doubtful and is not well supported by the relative percentages of the phosphoric acid in the crop. What has been said of the phosphoric acid in this particular appears to be equally applicable to the nitrogen.

These results bear out many previous observations to the effect that the use of the carbonates was accompanied by more phosphoric acid in the dry matter than the use of the chlorids.

Results with the English, or Flat, Turnip, 1905.

Below are given the crop yields and the analytical data in connection with certain of the experimental plats, which were obtained with flat, or English, turnips in 1905.

English or Flat, Turnip, Roots, 1905.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter. Phosphoric acid.	Per cent. in dry matter. Nitrogen.
12	Chlorids, limed once; ¼ soda, ¼ potash...........	240	1.32	3.01
3	Chlorids, limed once; 1 soda, ¼ potash...........	373	1.39	2.90
24	Chlorids, limed thrice; ¼ soda, ¼ potash..........	192	1.29	3.13
15	Chlorids, limed thrice; 1 soda, ¼ potash..........	294	1.35	3.09
36	Carbonates, limed once; ¼ soda, ¼ potash.........	227	1.45	3.07
27	Carbonates, limed once; 1 soda, ¼ potash.........	269	1.47	3.33
48	Carbonates, limed thrice; ¼ soda, ¼ potash........	246	1.30	3.28
39	Carbonates, limed thrice; 1 soda, ¼ potash........	372	1.39	2.67
6	Chlorids, limed once; ½ soda, ½ potash...........	390	1.29	2.41
2	Chlorids, limed once; 1 soda, ½ potash...........	402	1.42	2.80
18	Chlorids, limed thrice; ½ soda, ½ potash..........	340	1.26	2.64
14	Chlorids, limed thrice; 1 soda, ½ potash..........	377	1.26	2.46
30	Carbonates, limed once; ½ soda, ½ potash.........	311	1.41	2.77
26	Carbonates, limed once; 1 soda, ½ potash.........	385	1.42	2.54
23	Chlorids, limed thrice; ¾ soda, ¾ potash..........	376	1.33	2.51
13	Chlorids, limed thrice; 1 soda, ¾ potash..........	371	1.23	2.24
47	Carbonates, limed thrice; ¾ soda, ¾ potash........	404	1.41	2.60
37	Carbonates, limed thrice; 1 soda, ¾ potash........	392	1.38	2.42
22	Chlorids, limed thrice; 0 soda, 1 potash..........	369	1.28	2.55
20	Chlorids, limed thrice; ½ soda, 1 potash..........	392	1.28	2.22
17	Chlorids, limed thrice; 1 soda, 1 potash..........	382	1.31	2.32
34	Carbonates, limed once; 0 soda, 1 potash.........	414	1.40	2.53
32	Carbonates, limed once; ½ soda, 1 potash.........	420	1.41	2.22
29	Carbonates, limed once; 1 soda, 1 potash.........	358	1.40	2.40
46	Carbonates, limed thrice; 0 soda, 1 potash........	384	1.31	2.52
44	Carbonates, limed thrice; ½ soda, 1 potash........	399	1.43	2.59
41	Carbonates, limed thrice; 1 soda, 1 potash........	394	1.42	2.45

There seems in the foregoing table to be no definite nor constant relationship between the percentages of phosphoric acid and of nitrogen, nor between either one and the yields. In ten of the eleven instances where comparisons are permissible between the carbonates and chlorids there was a higher percentage of phosphoric acid in the crops where the carbonates were employed, and in the eleventh case the percentages were identical.

In each of the four cases when a quarter ration each of sodium and potassium salt was supplemented by an additional three-quarter ration of sodium salt the yield was greatly increased. At the same time the percentages of phosphoric acid in the crops ranged from .02 to .09 greater than where additional sodium was not present.

When a half ration each of potassium and sodium salt was supplemented by an additional half ration of sodium salt the crops were increased 12, 37, and 74 pounds, but in only one of the three instances was there a sufficiently greater percentage of phosphoric acid in the crop to have any significance.

When a three-quarter ration of each salt was supplemented by an additional quarter ration of sodium salt the yields, and the percentages of phosphoric acid, were in both cases less than where it was not added.

In the six instances when a full ration of potassium salt was supplemented by either a half or a full ration of sodium salt the yields, and percentages of phosphoric acid, were such as to furnish no evidence that there had been a positive gain in yield or in the percentage of phosphoric acid as a consequence of adding the sodium salt. These results are chiefly of interest when compared with those secured when the supply of potassium salt was small, for in the latter case the yield and the percentage of phosphoric acid in the crop were both increased by the application of further sodium salt in the manures.

The important point to be considered is whether the increased yields just mentioned were the result of the higher percentages of phosphoric acid or whether the latter were merely incidental accompaniments of the increased yields. When the quarter ration of each salt was used the yields were 240, 192, 227, and 246 pounds, with 1.32, 1.29, 1.45, and 1.30 as the accompanying percentages of phosphoric acid. Upon the addition of the three-quarter ration of sodium salt the corresponding yields rose to 373, 294, 269, and 372 pounds and the percentages of phosphoric acid to 1.39, 1.35, 1.47, and 1.39, respectively.

Upon comparing the other results in the table it will be seen, however, that there are several instances in which yields greater than any of those mentioned above were produced with smaller, or essentially as small, percentages of phosphoric acid. The yields here cited were furthermore all of them what would be properly considered as normal. The evidence afforded does not, therefore, fully uphold the idea that the yields were increased as the direct result of the presence of the higher percentages of phosphoric acid in the crop, but much evidence is afforded that the increase was due, possibly, to some direct function of sodium which it was capable of exercising in the absence of an abundance of potassium. The possible influence of the sodium salts upon the osmotic pressure, upon the reaction of the medium in which the plants are grown, and upon other factors is being studied by way of water culture, and these results will be published later.

Other results secured with the same kind of flat turnips in another experiment are of interest in this connection, particularly for the reason that the turnips were growing at the same time and were harvested shortly after those which have just been discussed. The soil in this permanent plat, (No. 45) was manured uniformly with phosphoric acid, potash, and nitrogen. In one instance the phosphoric acid was supplied in guano, in another in acid phosphate, and in a third in fine ground bone. The yields from the same areas as those given above were 406, 395, and 374 pounds, respectively, and the corresponding percentages of phosphoric acid were 0.93, 1.01, and 1.02. It will be seen that these yields were all above those obtained where the quarter ration of each salt was supplemented by a three-quarter ration of sodium salt, and at the same time the percentages of phosphoric acid in the dry matter of the crop were much less than in the cases which have just been considered. This still further lends support to the idea that the higher percentages of phosphoric acid accompanying the increased yields produced by the additional sodium salt were not the actual cause of the increased yields, but that they were merely an incidental accompaniment, due possibly to the solvent action upon the phosphates within the soil or to the ability of the plant to most easily take up phosphoric acid when it is combined with potassium or sodium.

With the hope of throwing additional light upon the relative influence of sodium and potassium salts on the percentages of nitrogen and phosphoric acid in certain crops, samples for analysis were taken from plats where a quarter ration of sodium was employed together with a full ration of potassium, and on the other hand from plats where a full ration of sodium salt was supplemented by a quarter ration of potassium salt. The results of these analyses are given below:

Radish, White Strasburg, Roots. 1905.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Phosphoric acid.	Nitrogen.
3	Chlorids, limed once; 1 soda, ¼ potash	456	1.10	3.50
9	Chlorids, limed once; ¼ soda, 1 potash	547	1.17	3.52
15	Chlorids, limed thrice; 1 soda, ¼ potash	438	1.08	4.11
21	Chlorids, limed thrice; ¼ soda, 1 potash	511	1.32	3.82
27	Carbonates limed once; 1 soda, ¼ potash	400	1.26	4.10
33	Carbonates limed once; ¼ soda, 1 potash	557	1.19	3.69
39	Carbonates limed thrice; 1 soda, ¼ potash	398	1.16	3.87
45	Carbonates, limed thrice; ¼ soda, 1 potash	522	1.08	3.51

It will be observed that, so far as concerns phosphoric acid, the percentages were in two cases higher where the larger amount of sodium salt was used. In the other two cases the percentages of phosphoric acid were lower, even though the yields were smaller in all four instances. In all but one of the four instances higher percentages of nitrogen accompanied the use of the larger proportion of sodium salts; yet, nevertheless, the crops were in all cases much smaller than where the larger proportion of potassium salt was applied. There is no good evidence that the excess of nitrogen inhibited growth, and still less that the phosphoric acid did so; but on the contrary, the limit to the size of the crop seems to have been determined chiefly by the supply of potassium, though, as had been abundantly shown by the experiments described elsewhere, sodium materially increases the crop when the supply of potassium is insufficient for its needs. The results with the English, or flat, turnip, which was also grown in the year 1905, will now be considered.

English, or Flat Turnip, Roots, 1905.

Plat No.	Special Manures Applied.	Yields, green, pounds.	Per cent. in dry matter.	
			Phosphoric acid.	Nitrogen.
3	Chlorids, limed once; 1 soda, ¼ potash...........	373	1.39	2.90
9	Chlorids, limed once; ¼ soda, 1 potash...........	413	1.15	2.49
15	Chlorids, limed thrice; 1 soda, ¼ potash..........	294	1.35	3.09
21	Chlorids, limed thrice; ¼ soda, 1 potash..........	406	1.26	2.29
27	Carbonates, limed once; 1 soda, ¼ potash.........	269	1.47	3.33
33	Carbonates, limed once; ¼ soda, 1 potash.........	402	1.09	2.35
39	Carbonates, limed thrice; 1 soda, ¼ potash........	372	1.39	2.67
45	Carbonates, limed thrice; ¼ soda, 1 potash........	344	1.23	2.74

It will be observed, in the case of the turnip, that in all four instances the percentages of phosphoric acid were unmistakably greater when the larger amount of sodium salt was used. The same was also true of the nitrogen, excepting in the last instance. The fact that greater yields accompanied smaller percentages of nitrogen and of phosphoric acid in three of the four cases can not be considered as furnishing evidence that the nitrogen and phosphoric acid inhibited growth, but that the growth was limited, as in the case of the radish, by the shortage of potassium. It would certainly be of much interest to ascertain if the extra phosphorus found in these plants in consequence of the employment of sodium salts is in inorganic or organic combinations within the plant, for in view of the recent work by Jordan, Hart, and Patten,* and by Tunnicliffe,† it might in some cases have marked influence upon the function of the plant as concerns its food value.

It may be seen by reference to the relative amounts of proteid and non-proteid nitrogen in the turnip roots (page 220), that a smaller proportion of proteid nitrogen accompanied an increase in the percentages of both phosphoric acid and nitrogen when the larger proportion of sodium was used, and that in the one instance where phosphoric acid only was increased the proportion of proteid and non-proteid nitrogen remained unchanged. These results, although too limited in number to be more than suggestive, certainly indicate that the increased percentages of phosphoric acid and nitrogen may not have increased the feeding value of the crop.

Concerning the Influence of Sodium and Potassium upon the Relative Percentages of Proteid and Non-Proteid Nitrogen.

In order to form some idea as to the influence of sodium and potassium upon the relative percentages of proteid and non-proteid nitrogen present in the crops, a few determinations were made for this purpose. The data are not sufficient to be conclusive, but are rather to be looked upon as suggestive until opportunity may be afforded us or others to pursue the subject further.

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*Technical Bulletin No. 1, N. Y. Agr. Experiment Station, Geneva.

†Arch. Internat. Pharmacop. et Thér. 16 (1906), No. 1-4, pp. 207-220, Abs. E. S. R. 18, p. 359.

The non-proteid nitrogen given below includes nitrogen in nitrates in amounts approximating 0.9 per cent. of the dry matter in the case of the radish and about half that quantity in the case of the turnips. In addition to these data it is desirable that determinations be made in order to ascertain the relative amounts of nitrate and of amido nitrogen in the individual cases, but the time at disposal has rendered this as yet impossible.

Below are given the analytical data which were secured:

Per cent. of Nitrogen in Different Combinations in the Dry Matter of the Roots (Crop of 1905).

Kind of Crop and of Sodium and Potassium Salts Used.	LIMED ONCE.				LIMED THREE TIMES.			
	1 soda, ½ potash.	Relative percentages of the total nitrogen in the two groups.	½ soda, 1 potash.	Relative percentages of the total nitrogen in the two groups.	1 soda, ½ potash.	Relative percentages of the total nitrogen in the two groups.	½ soda, 1 potash.	Relative percentages of the total nitrogen in the two groups.
Plat No..................	3	3	9	9	15	15	21	21
Turnip Roots. *Chlorids.*								
Total nitrogen.............	2.90	......	2.49	......	3.09	......	2.29	.....
Proteid nitrogen†..........	*	*	*	*	1.55	50.2	1.43	62.4
Non-proteid nitrogen.......	*	*	*	*	1.54	49.8	0.86	37.6
Plat No..................	27	27	33	33	39	39	45	45
Turnip Roots. *Carbonates.*								
Total nitrogen.............	3.33	......	2.35	......	2.67	......	2.74	.....
Proteid nitrogen...........	1.49	44.7	1.36	57.9	1.46	54.7	1.49	54.4
Non-proteid nitrogen.......	1.84	55.3	0.99	42.1	1.21	45.3	1.25	45.6
Plat No..................	3	3	9	9	15	15	21	21
Radish Roots. *Chlorids.*								
Total nitrogen.............	3.50	......	3.52	......	4.11	......	3.82	.....
Proteid nitrogen...........	1.36	38.8	1.48	42.1	1.49	36.3	1.35	35.3
Non-proteid nitrogen.......	2.14	61.2	2.04	57.9	2.62	63.7	2.47	64.7

*Not determined. †Determined by the official method of the A. O. A. C.

In the case of the turnip crops from plats Nos. 15 and 21 it will be seen that 62.4 per cent. of the total nitrogen was in the proteid combination when the full ration of potassium and quarter ration of sodium were employed, but in the instance when a full ration of sodium and a quarter ration of potassium were used it will be seen that only 50.2 per cent. of the total nitrogen was in proteid combinations. Quite similar results were secured in the case of the crops from plats Nos. 27 and 33. Also with the radish roots from plats Nos. 3 and 9 the results pointed in the same direction, though the difference was small. In the case of the turnips from plats Nos. 29 and 45 and of the radishes from plats Nos. 15 and 21 the results were practically alike, though in the latter case pointing slightly in the opposite direction from those first mentioned above. In view of the tendency of sodium salts to increase the percentage of phosphorus in certain of the plants which have been employed in these experiments, particularly when the supply of potassium was small, it would seem desirable that this question should be studied further in order that more conclusive data on this point may be secured.

In concluding the discussion of this phase of the results with the sodium salts it may be said that, as a whole, they show that the use of sodium carbonate and potassium carbonate has been followed as a rule by higher percentages of phosphoric acid in the crop than the use of the chlorids.

It has been very conclusively shown in the field that, in the presence of limited supplies of potassium salts, sodium salts are important factors in increasing the yields of certain crops. This was particularly striking in the case of the mangel-wurzel, even when a very large quantity of potassium was employed.

The results show in a most conclusive manner that by the employment of sodium salts, particularly where the supply of potash is limited, the percentages of phosphorus in the crop are notably increased. Much evidence has also been deduced to show that the increased crops accompanying the employment of sodium salts under the circumstances mentioned were not in consequence of the presence of larger amounts of phosphoric acid in the plant, but that the gain was possibly due to a direct physiological function of the sodium or to other causes which will be discussed in a later publication.

No constant nor definite relationship has been observed between the percentages of phosphoric acid and nitrogen in the crops. This has been somewhat of a surprise in view of the frequent references in the agricultural literature to the effect that "the phosphorus goes with the nitrogen," yet this may have been due in part to our having dealt chiefly with root crops. It is possible that further light may be thrown upon this point when it becomes convenient to determine more fully the individual nitrogenous compounds of these crops, a work that is in prospect, in connection with a careful study of the influence of sodium salts upon the organic constituents of plants.

COULD THE FREQUENT BENEFICIAL EFFECT OF SODIUM SALTS HAVE BEEN DUE TO THEIR ENABLING THE PLANT TO TAKE UP ADDITIONAL LIME OR MAGNESIA?

It becomes important, in connection with a discussion of the reason for the beneficial action of sodium salts in these experiments, to consider whether any part of the benefit can, under the circumstances, be attributed to a "setting free" of lime or magnesia.

Below are given the yields of Strasburg radish upon the same area basis as those given previously in connection with the discussion of the nitrogen and phosphoric acid percentages. Accompanying these are the respective percentages of lime and magnesia found in the dry matter of the crops.

Radish, White Strasburg, Roots, 1899.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Calcium oxid.	Magnesium oxid.
12	Chlorids, unlimed; ¼ soda, ¼ potash	547	1.38	0.73
3	Chlorids, unlimed; 1 soda, ¼ potash,	709	1.09	0.67
24	Chlorids, limed; ¼ soda, ¼ potash	432	1.56	1.02
15	Chlorids, limed; 1 soda, ¼ potash	685	1.19	0.73
36	Carbonates, unlimed; ¼ soda, ¼ potash	547	1.17	0.77
27	Carbonates, unlimed; 1 soda, ¼ potash	722	1.27	0.94
48	Carbonates, limed; ¼ soda, ¼ potash	432	1.53	1.17
39	Carbonates, limed; 1 soda, ¼ potash	540	1.07	0.76
6	Chlorids, unlimed; ½ soda, ½ potash	797	1.02	0.65
2	Chlorids, unlimed; 1 soda, ½ potash	834	1.06	0.58
18	Chlorids, limed; ½ soda, ½ potash	662	1.43	0.56
14	Chlorids, limed; 1 soda, ½ potash	766	1.32	0.63
30	Carbonates, unlimed; ½ soda, ½ potash	776	1.24	0.75
26	Carbonates, unlimed; 1 soda, ½ potash	817	1.23	0.90
42	Carbonates, limed; ½ soda, ½ potash	621	1.19	0.72
38	Carbonates, limed; 1 soda, ½ potash	662	1.17	0.67

It will be observed that in three of the four cases where a quarter ration of each salt was supplemented by the addition of a three-quarter ration of sodium salt to the great advantage of the crop, that the percentages of both lime and magnesia were less than where less soda was employed. It will also be seen that the benefit was apparently not due to changes in the relative amounts of lime and magnesia taken up by the crop, as might be suggested by one familiar with the work of Loew and his fellow-workers, since these changes were not of such a character nor of such a degree as to explain the benefit derived from the sodium salts. It must, nevertheless, be borne in mind that this is based upon the analysis of the roots and that changes in the composition of the tops may have resulted which may have been of advantage. It is hoped later to investigate this point.

By similar comparisons it will be seen that the addition of a half ration of sodium salt to a half ration of each was accompanied by a depression of the magnesia in two cases and by an increase in two cases. Concerning lime, the percentages were slightly less in three instances and slightly greater in one instance when the additional sodium salt was employed.

These results do not indicate that the increased yields could probably have been due to indirect action of the sodium salts in "setting free" either lime or magnesia.

Below are given the results with the English, or flat, turnip in 1899.

English, or Flat, Turnip, 1899.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Calcium oxid.	Magnesium oxid.
24	Chlorids, limed; ½ soda, ½ potash	214	1.32	0.60
15	Chlorids, limed; 1 soda, ½ potash	293	1.26	0.69
36	Carbonates, unlimed; ½ soda, ½ potash	149	1.45	0.69
27	Carbonates, unlimed; 1 soda, ½ potash	212	1.36	0.64

In one instance the magnesia and in two instances the lime was lower where extra sodium salts were employed, even notwithstanding the greater yields which resulted.

Below follow the results with the mangel-wurzel (Norbiton giant beet):

Mangel-Wurzel, Roots, 1899.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Calcium oxid.	Magnesium oxid.
24	Chlorids, limed; ½ soda, ½ potash	421	0.24	0.56
15	Chlorids, limed; 1 soda, ½ potash	682	0.26	0.50
48	Carbonates, limed; ½ soda, ½ potash	299	0.25	0.74
39	Carbonates, limed; 1 soda, ½ potash	601	0.29	0.48

In the case of this crop the gains from the use of additional amounts of the sodium salts were enormous, yet in both instances the percentages of magnesia were less when it was employed. The percentages of lime were slightly higher when the extra sodium salts were employed.

These results, like the preceding, seem to afford no basis for concluding that the soda had acted as an indirect manure by virtue of placing more lime or magnesia at the disposal of the plants.

In view of the fact that a smaller crop accompanied the greater rather than the lesser depression of the magnesia, there is less reason than otherwise to hold that this change in the relation of the lime and magnesia was the actual cause of the increased yields, particularly as the ratio of the lime to magnesia in the dry matter, was wider in the case of the largest than in the next to the largest crop.

Below are given the results with the carrot, which was grown in the year 1899:

Carrot, Roots, 1899.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Calcium oxid.	Magnesium oxid.
24	Chlorids, limed; ¼ soda, ¼ potash	343	0.78	0.39
15	Chlorids, limed; 1 soda, ¼ potash	483	0.74	0.32
48	Carbonates, limed; ¼ soda, ¼ potash	373	0.70	0.41
39	Carbonates, limed; 1 soda, ¼ potash	483	0.68	0.35

It will be seen that in the case of the carrot the percentages of lime and magnesia were lessened in every instance where the quarter ration of each salt was further supplemented by a three-quarter ration of sodium salt, even notwithstanding the greater yields.

No ground for benefit to the crop by virtue of a liberation of lime and magnesia is afforded by the results, nor does it seem probable that the relatively smaller percentage of magnesia could have been responsible for the increased yields.

The following results were secured with chicory:

Chicory, Roots, 1899.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Calcium oxid.	Magnesium oxid.
24	Chlorids, limed; ¼ soda, ¼ potash	200	0.22	0.25
15	Chlorids, limed; 1 soda, ¼ potash	189	0.24	0.25
48	Carbonates, limed; ¼ soda, ¼ potash	234	0.25	0.32
39	Carbonates, limed; 1 soda, ¼ potash	205	0.26	0.32

It will be at once observed that the yields were lower in both cases where the additional amount of sodium salt was used, the percentages of magnesium oxid were identical, and those of calcium oxid showed no significant differences.

The following results were obtained with the white Strasburg radish, which was grown in the year 1901:

Radish, White Strasburg, Roots, 1901.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Calcium oxid.	Magnesium oxid.
22	Chlorids, limed; 0 soda, 1 potash	248	1.10	0.64
20	Chlorids, limed; ½ soda, 1 potash	261	1.13	0.66
19	Chlorids, limed; ¾ soda, 1 potash	243	1.00	0.53
34	Carbonates, unlimed; 0 soda, 1 potash	288	0.96	0.57
32	Carbonates, unlimed; ½ soda, 1 potash	291	0.95	0.59
31	Carbonates, unlimed; ¾ soda, 1 potash	279	0.84	0.50
46	Carbonates, limed; 0 soda, 1 potash	228	1.08	0.58
44	Carbonates, limed; ½ soda, 1 potash	252	0.86	0.51
43	Carbonates, limed; ¾ soda, 1 potash	243	0.89	0.57
12	Chlorids, unlimed; ¼ soda, ¼ potash	234	1.13	0.65
3	Chlorids, unlimed; 1 soda, ¼ potash	216	0.90	0.53

When a sodium salt was employed in addition to a full ration of potassium salt there was no positive evidence of an increase in yield due to this fact, excepting possibly where only an extra half ration of sodium salt was added. In the single comparison of a quarter ration each of the potassium and of the sodium salt with the same supplemented by a three-quarter ration of sodium salt, the yield was less when the amount of the latter salt was increased.

There was some slight evidence of a tendency of the sodium salts to lower the percentages of magnesium oxid, and still stronger evidence of a lowering of the percentages of calcium oxid.

The following results were obtained with chicory roots grown in 1901:

Chicory, Roots, 1901.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Calcium oxid.	Magnesium oxid.
22	Chlorids, unlimed; 0 soda, 1 potash	243	0.24	0.17
20	Chlorids, unlimed; ½ soda, 1 potash	243	0.24	0.17
19	Chlorids, unlimed; ¾ soda, 1 potash	243	0.24	0.16
34	Carbonates, unlimed; 0 soda, 1 potash	162	0.23	0.17
32	Carbonates, unlimed; ½ soda, 1 potash	180	0.24	0.15
31	Carbonates, unlimed; ¾ soda, 1 potash	194	0.24	0.16
24	Chlorids, limed; ¼ soda, ¼ potash	194	0.22	0.24
15	Chlorids, limed; 1 soda, ¼ potash	225	0.23	0.24
48	Carbonates, limed; ¼ soda, ¼ potash	131	0.21	0.26
39	Carbonates, limed; 1 soda, ¼ potash	117	0.24	0.27
	Chicory, Tops, 1901.			
48	Carbonates, limed; ¼ soda, ¼ potash	*	2.71	1.81
39	Carbonates, limed; 1 soda, ¼ potash	*	2.22	1.11

*Weight not determined.

The addition of a sodium salt to a full ration of potassium salt was accompanied by an apparent gain in the crop of chicory roots in but one of the two series. No depression of the calcium oxid in the plant, and only suggestions of a possible depression of the magnesium oxid, followed the introduction of the sodium salt in the manures.

The addition to a quarter ration of each salt of an extra three-quarter ration of the sodium salt resulted in a greater yield in one case and in a smaller yield in the other case.

No marked influence of the sodium salt upon the percentages of calcium oxid and of magnesium oxid seemed to have resulted.

In the case of the chicory tops the percentages of both magnesium and calcium oxids were decidedly and unquestionably lessened as a consequence of increasing the application of sodium salt, and the ratio of magnesia to lime in the tops was changed from 1: 1.5 to 1:2. Whether this change in the ratio affected the growth favorably or unfavorably remains to be determined.

Below are given the results secured with the carrot crop, which was grown in the year 1901:

Carrot, Roots, 1901.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Calcium oxid.	Magnesium oxid.
24	Chlorids, limed; ¼ soda, ¼ potash	315	0.50	0.32
15	Chlorids, limed; 1 soda, ¼ potash	313	0.51	0.27
48	Carbonates, limed; ¼ soda, ¼ potash	315	0.50	0.30
39	Carbonates, limed; 1 soda, ¼ potash	306	0.51	0.35
	Carrot, Tops, 1901.			
48	Carbonates, limed; ¼ soda, ¼ potash	*	1.87	0.96
39	Carbonates, limed; 1 soda, ¼ potash	*	1.54	0.89

*Not weighed.

No gain in carrot roots resulted when a three-quarter ration of sodium salt was added to a quarter ration of each.

The contradictory and trifling differences in the percentages of magnesium oxid and calcium oxid are such that no definite relationship between them and the amount of sodium salt in the manures can be established.

In the case of the tops, just as with the chicory tops, the employment of a larger amount of the sodium salt was followed by a depression of the percentages of calcium and magnesium oxids. The ratio of magnesia to lime was changed but about .2 in this instance, and in a direction opposite to that of the change in the case of the chicory tops.

The results in connection with the white Strasburg radish, raised in the year 1905, are given below:

Radish, White Strasburg, Roots, 1905.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter. Calcium oxid.	Per cent. in dry matter. Magnesium oxid.
12	Chlorids, limed once; ½ soda, ½ potash...........	398	1.69	0.79
3	Chlorids, limed once; 1 soda, ½ potash.	456	1.42	0.69
24	Chlorids, limed thrice; ½ soda, ½ potash..........	324	1.87	0.83
15	Chlorids, limed thrice; 1 soda, ½ potash..........	438	1.59	0.78
36	Carbonates, limed once; ½ soda, ½ potash.........	372	1.66	0.80
27	Carbonates, limed once; 1 soda, ½ potash.........	400	1.58	0.78
48	Carbonates, limed thrice; ½ soda, ½ potash........	375	1.67	0.80
39	Carbonates, limed thrice; 1 soda, ½ potash........	398	1.52	0.76
11	Chlorids, limed once; ¾ soda, ¾ potash...........	557	1.31	0.71
1	Chlorids, limed once; 1 soda, ¾ potash...........	550	1.21	0.44
23	Chlorids, limed thrice; ¾ soda, ¾ potash..........	498	1.53	0.59
13	Chlorids, limed thrice; 1 soda, ¾ potash..........	547	1.34	0.66
35	Carbonates, limed once; ¾ soda, ¾ potash.........	553	1.08	0.70
25	Carbonates, limed once; 1 soda, ¾ potash.........	556	1.20	0.64

Radish, White Strasburg, Roots, 1905.—Concluded.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Calcium oxid.	Magnesium oxid.
47	Carbonates, limed thrice; ¾ soda, ¾ potash	514	1.32	0.65
37	Carbonates, limed thrice; 1 soda, ¾ potash	555	1.37	0.59
10	Chlorids, limed once; 0 soda, 1 potash	522	1.12	0.83
8	Chlorids, limed once; ½ soda, 1 potash	542	1.18	0.58
5	Chlorids, limed once; 1 soda, 1 potash	574	1.00	0.76
22	Chlorids, limed thrice; 0 soda, 1 potash	522	1.28	0.95
20	Chlorids, limed thrice; ½ soda, 1 potash	553	1.52	0.73
34	Carbonates, limed once; 0 soda, 1 potash	548	1.03	0.85
32	Carbonates, limed once; ½ soda, 1 potash	555	1.23	0.62
46	Carbonates, limed thrice; 0 soda, 1 potash	508	1.30	0.85
41	Carbonates, limed thrice; 1 soda, 1 potash	532	1.24	0.79

In all four instances where a quarter ration each of the two salts was supplemented by a three-quarter ration of sodium salt unmistakable gains in the crops resulted and the percentages of both calcium and magnesium oxids were lessened in all four cases in consequence of its addition, but the ratios between the two remained practically unchanged.

Where a three-quarter ration each of the two salts was supplemented by an additional quarter ration of sodium salt no positive advantage resulted. The yields were greater in three of the four cases, though in one of these cases the difference was wholly insignificant. The percentages of magnesium oxid in the plants were lessened by the soda in three of the four cases, but the same was true of the calcium oxid in only two of the cases.

Where a full ration of potassium salt was supplemented by a half ration of sodium salt the yields were a little greater in every one of the three cases. The percentage of calcium oxid was increased in each of the three instances, but the per cent. of magnesium oxid was decreased in every case.

This lessening of the magnesia in its relation to the lime is of special interest in view of the increased crop and in view of the injury to the crop in every case by extra liming. The magnesia-lime relationship idea of Loew would seem to fail in this case to explain the benefit from the soda, particularly in view of the fact that liming increased the percentage of calcium oxid in the crop.

The results secured with the English, or flat, turnip, which was grown in the year 1905, are given below:

Turnip, Flat, Roots, 1905.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Calcium oxid.	Magnesium oxid.
12	Chlorids, limed once; ¼ soda, ¼ potash	240	0.99	0.40
3	Chlorids, limed once; 1 soda, ¼ potash	373	0.87	0.31
24	Chlorids, limed thrice; ¼ soda, ¼ potash	192	1.17	0.38
15	Chlorids, limed thrice; 1 soda, ¼ potash	294	0.99	0.37
36	Carbonates, limed once; ¼ soda, ¼ potash	227	1.04	0.40
27	Carbonates, limed once; 1 soda, ¼ potash	269	0.90	0.38
48	Carbonates, limed thrice; ¼ soda, ¼ potash	246	1.15	0.41
39	Carbonates, limed thrice; 1 soda, ¼ potash	372	0.89	0.39
6	Chlorids, limed once; ½ soda, ½ potash	390	0.83	0.37
2	Chlorids, limed once; 1 soda, ½ potash	402	0.80	0.35
18	Chlorids, limed thrice; ½ soda, ½ potash	340	1.00	0 .35
14	Chlorids, limed thrice; 1 soda, ½ potash	377	0.93	0 .36
30	Carbonates, limed once; ½ soda, ½ potash	311	1.00	0.36
26	Carbonates, limed once; 1 soda, ½ potash	385	0.87	0.36

Turnip, Flat, Roots, 1905.—Concluded.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter. Calcium oxid.	Per cent. in dry matter. Magnesium oxid.
23	Chlorids, limed thrice; ¼ soda, ¼ potash	376	1.02	0.33
13	Chlorids, limed thrice; 1 soda, ¼ potash	371	0.90	0.38
47	Carbonates, limed thrice; ¼ soda, ¼ potash	404	0.88	0.37
37	Carbonates, limed thrice; 1 soda, ¼ potash	392	0.92	0.38
22	Chlorids, limed once; 0 soda, 1 potash	369	0.98	0.50
20	Chlorids, limed once; ½ soda, 1 potash	392	1.03	0.41
17	Chlorids, limed once; 1 soda, 1 potash	382	0.91	0.36
34	Carbonates, limed once; 0 soda, 1 potash	414	0.78	0.46
32	Carbonates, limed once; ½ soda, 1 potash	420	0.81	0.34
29	Carbonates, limed once; 1 soda, 1 potash	358	0.90	0.35
46	Carbonates, limed thrice; 0 soda, 1 potash	384	0.88	0.42
44	Carbonates, limed thrice; ½ soda, 1 potash	399	0.89	0.41
41	Carbonates, limed thrice; 1 soda, 1 potash	394	0.74	0.46

When the quarter ration of each salt was supplemented by an additional three-quarter ration of the sodium salt, the yields were considerably greater in all four cases. The percentages of calcium and magnesium oxids, on the contrary, were lessened in each instance. In three cases the ratio between lime and magnesia was materially changed and in the other case not; hence the gain in all cases can not be attributable to this fact.

In the cases given where a half ration each of the two salts was supplemented by an application of a half ration of sodium salt the yields were only moderately increased, and in one case only was the ratio of magnesia to lime practically reduced. The absolute percentages of magnesium oxid were not positively affected, but in all three instances the percentages of calcium oxid were depressed by the extra sodium salt.

A three-quarter ration each of the sodium and potassium salts seemed to be sufficient to nullify the good effects of further amounts of sodium salts, for in both instances where an additional quarter ration of the sodium salt was applied the yields were slightly less than without it. When the additional sodium salt was used the percentages of magnesium oxid in the dry matter were in both cases slightly increased. The same was true of the calcium oxid in but one case, while in the other instance the reverse was true.

The supplementing of a full ration of potassium salt with a half ration of sodium salt was accompanied in all three cases by slightly greater yields, but the addition of a full ration of sodium salt was not always accompanied by an increase of crop. Many of these differences were, however, too small to have much significance. The percentages of calcium and magnesium oxid exhibit much irregularity and do not show the same positive depressing effect of the sodium salt which was observed when only quarter or half rations of each salt were employed.

In conclusion it may be said that the foregoing results fail to give evidence that the sodium salts were probably beneficial by virtue of their setting free additional amounts of either calcium or magnesium oxids, and it seems also improbable that the benefit observed could have been due to changes in the relative amounts of lime and magnesia taken up by the plants.

DATA CONCERNING THE INFLUENCE OF SODIUM AND POTASSIUM SALTS UPON THE GROWTH OF CERTAIN PLANTS AND UPON THE PERCENTAGES OF SODIUM AND POTASSIUM OXIDS IN THE DRY MATTER.

The results about to be described were obtained upon the same plats of land as those which have been mentioned previously, hence further attention here to the scheme of manuring, excepting in so far as it concerns the respective potassium and sodium salts, is unnecessary.

The following results were obtained in the year 1898:

Millet, Golden, 1898.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Sodium oxid.	Potassium oxid.
36	Carbonates, unlimed; ¼ soda, ¼ potash	132	0.14	1.09
27	Carbonates, unlimed; 1 soda, ¼ potash	102	0.17	0.97
48	Carbonates, limed; ¼ soda, ¼ potash	142	0.05	1.16
39	Carbonates, limed; 1 soda, ¼ potash	155	0.07	1.09

In the case of the millet the yield was in one instance greater and in the other less where the extra amount of sodium salt was added.

In each instance the percentage of sodium oxid was increased and that of potassium oxid lessened when the extra three-quarter ration of the sodium salt was employed. The lack of positive evidence of benefit to the yield from the employment of an additional amount of sodium salt and the small quantities of sodium oxid found in the millet in any case furnish a striking contrast to the results secured with certain other varieties of plants.

Below are given the data secured with the white Strasburg radish in 1899:

Radish, White Strasburg, Roots, 1899.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Sodium oxid.	Potassium oxid.
12	Chlorids, unlimed; ¼ soda, ¼ potash	547	3.83	3.69
3	Chlorids, unlimed; 1 soda, ¼ potash	709	6.38	3.76
24	Chlorids, limed; ¼ soda, ¼ potash	432	4.03	3.62
15	Chlorids, limed; 1 soda, ¼ potash	685	6.01	2.85
36	Carbonates, unlimed; ¼ soda, ¼ potash	547	3.56	3.05
27	Carbonates, unlimed; 1 soda, ¼ potash	722	6.57	2.90
48	Carbonates, limed; ¼ soda, ¼ potash	432	3.69	3.61
39	Carbonates, limed; 1 soda, ¼ potash	540	6.50	2.81
6	Chlorids, unlimed; ½ soda, ½ potash	797	3.67	6.12
2	Chlorids, unlimed; 1 soda, ½ potash	834	4.14	6.72
18	Chlorids, limed; ½ soda, ½ potash	662	3.62	5.54
14	Chlorids, limed; 1 soda, ½ potash	766	5.12	5.19
30	Carbonates, unlimed; ½ soda, ½ potash	776	3.60	5.59
26	Carbonates, unlimed; 1 soda, ½ potash	817	4.50	4.98
42	Carbonates, limed; ½ soda, ½ potash	621	4.07	5.48
38	Carbonates, limed; 1 soda, ½ potash	662	5.72	5.27

It will be observed that the yields were increased 162, 253, 175, and 108 pounds where the quarter rations of the two salts were supplemented by a three-quarter ration of sodium salt. Expressed in another way, the gains amounted to 30, 69, 32, and 22 per cent.

It will be seen that in all four instances the percentages of sodium oxid in the plant were greatly increased where the extra application of the sodium salt had been made. In three of the four instances a depression of the percentage of potassium oxid was also observed. In the case of the crops from plats Nos. 15 and 24 the percentage of potassium oxid in one instance was 3.62, but where an extra application of a three-quarter ration of sodium salt was made the per cent. of potassium oxid was but 2.85. In the case of the crops from plats 39 and 48 the percentage of potassium oxid was depressed from 3.61 to 2.81. In both of these cases of marked depression of the potash, the land had been limed.

Where a half ration of sodium salt was added to a half ration each of potassium and sodium salts, the yields were greater in all four instances. In every instance where the extra sodium salt was employed the per cent. of sodium oxid in the crop was very decidedly increased. At the same time the per cent. of potassium oxid was depressed in three of the four cases. In other words, very much larger crops were produced in all but two of the cases with the smaller percentages of potassium oxid in the crop. It appears, therefore, that the larger percentages of potassium oxid which were met with in the crop were therefore not necessary to its production, at least provided a liberal supply of sodium was present in the manures. The question therefore arises why the larger amount of potassium actually in the crop was not utilized to advantage when the extra sodium salt was not employed. Furthermore, the fact that larger crops resulted and that a more effective use was made of the potassium supply when the quantity of sodium salt in the manures was increased is certainly a very suggestive feature.

When these results are considered in connection with the yields where larger amounts of potassium salts were used,* it will be seen that the advantage of employing the sodium salt seemed to become less as the potassium salt in the manures was increased. The fact that on account of the greater yields larger total amounts of potassium oxid were usually removed per acre where the extra sodium salt was employed in no way lessens the evidence that the sodium salt had probably proved highly beneficial in some other way than as an agent in liberating potassium.

The results with the English or flat, turnip in 1899 now follow:

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* Bul. 104 R. I. Agl. Expt. Station (1905) p. 77.

Turnip, Flat, Roots, 1899.

Plat No.	Special Manures Applied.	Yield, green pounds.	Per cent. in dry matter.	
			Sodium oxid.	Potassium oxid.
24	Chlorids, limed; ¼ soda, ¼ potash	214	2.37	2.88
15	Chlorids, limed; 1 soda, ¼ potash	293	5.05	2.13
36	Carbonates, unlimed; ¼ soda, ¼ potash	149	2.88	2.54
27	Carbonates, unlimed; 1 soda, ¼ potash	212	2.31	3.21

The addition of a three-quarter ration of sodium salt to the quarter ration of the two salts resulted in gains of 37 and 42 per cent. in turnip roots. In the case of plats Nos. 24 and 15 the percentage of sodium oxid in the plant was increased and of the potassium oxid decreased in consequence of the addition of the extra sodium salt. The case of plats Nos. 27 and 36 shows exactly the reverse. These results, particularly as concerns the sodium oxid, are so unusual as to arouse a suspicion that there may have been an interchange of the samples from the two plats. It may, nevertheless, be attributable to some obscure cause. A similar observation will be referred to later in connection with the same crop in 1905 (plats Nos. 39 and 48).

Below are given results secured with the mangel-wurzel (Norbiton giant beet), in 1899:

Beet, Norbiton Giant, 1899.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter. Sodium oxid.	Per cent. in dry matter. Potassium oxid.
24	Chlorids, limed; ¼ soda, ¼ potash	421	2.65	1.24
15	Chlorids, limed; 1 soda, ¼ potash	682	4.63	0.84
48	Carbonates, limed; ¼ soda, ¼ potash	299	2.92	1.10
39	Carbonates, limed; 1 soda, ¼ potash	601	5.10	0.81

The employment of an extra three-quarter ration of sodium salt to supplement the quarter rations of the two salts resulted in a gain in the yield of beets amounting to 62 per cent. in one case and to over 100 per cent. in the other case. The results agree with those obtained with the radish in showing a greatly increased percentage of sodium oxid and a decreased percentage of potassium oxid as a result of the use of the extra sodium salt.

In view of the fact that, with percentages of .81 and .84 of potassium oxid, crops amounting to 601 and 682 pounds were produced, it is rather surprising that where higher percentages of potassium oxid were present the crops should have been so much smaller, unless some special physiological function is ascribed to the sodium salt. This view of the matter is still further reinforced by the results in connection with the radish. Furthermore, in two cases with the radish, increased yields and percentages of potassium oxid accompanied the use of sodium salts. It would appear, therefore, that the claim can not be logically made in this case that the amounts of potassium oxid which equalled 1.10 and 1.24 per cent. were sufficient to, or probably did, inhibit growth. It is, of course, recognized that the sodium salt may have affected beneficially the moisture conditions of the soil, the osmotic pressure of the soil solution, or other physical or biological soil factors, yet the influence upon these would hardly seem to be sufficient to explain the increased yields. It will be borne in mind that it has already been shown in another connection that the sodium salt is a powerful factor in aiding the transportation of phosphorus into the plant, but at the same time it was shown that the extra phosphorus was apparently an accompaniment of the increased crops rather than a cause of the increase.

Below are given results with the carrot obtained in connection with the crop of 1899:

Carrot, Roots, 1899.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Sodium oxid.	Potassium oxid.
24	Chlorids, limed; ½ soda, ½ potash	343	3.00	2.09
15	Chlorids, limed; 1 soda, ½ potash	483	3.77	2.11
48	Carbonates, limed; ½ soda, ½ potash	373	2.89	2.36
39	Carbonates, limed; 1 soda, ½ potash	483	3.88	1.30

It will be observed that greatly increased yields, higher percentages of sodium oxid, and in one of the cases a much lower percentage of potassium oxid in the crop resulted when an extra amount of sodium salt was applied in the manures.

The results with chicory, which was grown in the same year, were as follows:

Chicory, Roots, 1899.

Plats No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Sodium oxid.	Potassium oxid.
24	Chlorids, limed; ¼ soda, ¼ potash	200	0.80	0.48
15	Chlorids, limed; 1 soda, ¼ potash	189	1.01	0.62
48	Carbonates, limed; ¼ soda, ¼ potash	234	0.81	0.45
39	Carbonates, limed; 1 soda, ¼ potash	205	1.04	0.37

It will be observed that the yields of chicory stand in marked contrast to those of the beet, turnip, radish, and carrot, for there was a smaller crop of chicory roots in each case when an extra three-quarter ration of the sodium salt was added. Another feature observed in but one or two cases previously, with other crops, was the greater percentage of potassium oxid in one of the crops where the extra amount of sodium salt was employed. It will be observed that the per cent. of sodium oxid was increased in each instance where the extra sodium salt was used.

These results seem to indicate that sodium is a less important factor in connection with chicory than with many other of the root crops. The percentages of potassium oxid and of sodium oxid in the roots were much less than in the case of the radish and turnip.

Results with Various Crops Grown in 1901.

The season of 1901 was quite different from that of 1899; in the former year the rainfall of the month of April amounted to 2.63 inches, that of May to 1.88 inches, that of June to 1.87 inches, and that of July to 2.71 inches, making a total of 9.09 inches.

In 1901 the rainfall for the corresponding months amounted to 8.78, 6.98, 1.32 and 4.05 inches, making a total of 21.13 inches for the four months. Attention is also called to the fact that the application of acid phosphate was increased in 1901 from 600 pounds to 1,296 pounds per acre. The application of magnesium sulfate was also increased from 420 to 600 pounds per acre. In 1899 the application of carbonate of potash, upon which all of the other applications of potassium and sodium salts were based, amounted to 300 pounds per acre. In 1900 the amount was reduced to 240 pounds, and in 1901 it was further reduced to 210 pounds per acre.

Below are given the results so far as concerns yields and the percentages of potassium oxid and sodium oxid in the dry matter obtained in connection with certain of the crops grown in 1901:

Radish, White Strasburg, Roots, 1901.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Sodium oxid.	Potassium oxid.
22	Chlorids, limed; 0 soda, 1 potash	248	1.43	9.41
20	Chlorids, limed; ½ soda, 1 potash	261	1.95	9.81
19	Chlorids, limed; ¾ soda, 1 potash	243	1.40	11.05
34	Carbonates, unlimed; 0 soda, 1 potash	288	0.91	10.66
32	Carbonates, unlimed; ½ soda, 1 potash	291	1.52	10.73
31	Carbonates, unlimed; ¾ soda, 1 potash	279	1.65	11.55
46	Carbonates, limed; 0 soda, 1 potash	228	0.97	9.42
44	Carbonates, limed; ½ soda, 1 potash	252	1.56	9.21
43	Carbonates, limed; ¾ soda, 1 potash	243	1.60	10.00
12	Chlorids, unlimed; ¼ soda, ¼ potash	234	3.09	5.42
3	Chlorids, unlimed; 1 soda, ¼ potash	216	3.55	6.03

In the limed series receiving chlorids and in the unlimed series receiving carbonates no positive evidence is afforded of benefit to the yield from adding a sodium salt to the full ration of potassium salt. If the results in the limed series receiving carbonates were considered by themselves it might be concluded that the added sodium salt had been beneficial in the presence of the full ration of potassium salt, but in view of the results which have just been cited it seems more probable that the differences in this latter case were merely incidental and due to an abnormally low yield on plat No. 46.

In two of the three series where the full ration of potassium salt was supplemented by additional amounts of sodium salt there seems to be no escape from the conclusion that the percentage of sodium oxid in the crop was increased. In the third of the series the evidence is inconclusive, because the percentage of sodium oxid in the plants from plat No. 22 appears for some reason to be unusually large. Taken as a whole, the results in the three series go to show that in this particular case the employment of the sodium salt failed to conserve the potassium supply of the soil and manures, but that rather larger amounts of potassium oxid were removed from the soil where the sodium salt had been added.

In striking contrast to the result with the radish in 1899 it will be seen that the yield produced by employing a quarter ration each of the potassium and sodium salt (plat No. 12) was not increased when an additional application of a three-quarter ration of sodium salt was made (plat No. 3). The results agree, however, with those of 1899 in showing an increased percentage of sodium oxid in the crop where a greater amount of sodium salt was added to the soil; yet they are quite the opposite of those of 1899 in showing that more potassium oxid was present in the dry matter of the crop in the case where the additional sodium salt was employed.

In how far these striking contrasts with the results of the year 1899 are due to the smaller size of the radishes, to the increase in the amounts of phosphate and of magnesium sulfate employed, and in what measure they were determined by the greater rainfall remains to be positively ascertained. It is probably true that the heavy rainfall of 1901 and the accompanying lack of clear weather explain the smaller size of the radish roots most satisfactorily, and the heavy rainfall was also most favorable to a chemical action of the sodium salt upon the potassic compounds of the soil by which the potassium could be rendered available to the plant. Perhaps this latter action alone explains the apparent failure of the sodium salt to act as a conserver of potassium because of more potassium compounds being rendered available and more of the sodium, in consequence of the chemical transformations, passing into less readily soluble combinations. It is also possible that the stage of growth of the plant played some part, though at present this does not seem to have been so important a factor in affecting the results as the unusual amount of rainfall.

Below are given the results secured with chicory:

Chicory, Roots, 1901.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Sodium oxid.	Potassium oxid.
22	Chlorids, limed; 0 soda, 1 potash	243	0.67	1.82
20	Chlorids, limed; ½ soda, 1 potash	243	0.72	1.90
19	Chlorids, limed; ¾ soda, 1 potash	243	0.52	1.97
34	Carbonates, unlimed; 0 soda, 1 potash	162	0.34	2.02
32	Carbonates, unlimed; ½ soda, 1 potash	180	0.51	1.89
31	Carbonates, unlimed; ¾ soda, 1 potash	194	0.52	2.16
24	Chlorids, limed; ¼ soda, ¼ potash	194	0.96	0.63
15	Chlorids, limed; 1 soda, ¼ potash	225	1.18	0.62
48	Carbonates, limed; ¼ soda, ¼ potash	131	0.84	0.55
39	Carbonates, limed; 1 soda, ¼ potash	117	1.19	0.50
	Chicory, Tops, 1901.			
48	Carbonates, limed; ¼ soda, ¼ potash	....	2.29	0.76
39	Carbonates, limed; 1 soda, ¼ potash	....	3.84	0.97

In the limed chlorid series where the full ration of potassium salt was supplemented by a half and three-quarter ration of sodium salt, it will be seen that the yields were in all cases identical.

In the unlimed series where the carbonates were employed the addition of increasing amounts of the sodium salt was accompanied by an apparent increase in the crop, though these differences may possibly have been merely incidental and hence without significance. In the series first mentioned above, no positive evidence was afforded of an increased percentage of sodium oxid in the crop, and furthermore the percentages of potassium oxid were greater, rather than less, where the extra sodium salt had been used.

In the unlimed carbonate series the percentage of sodium oxid in the roots had been apparently increased by the addition of the sodium salt in the manures. There was, however, owing to the variation in results, no positive evidence of an increase or depression of the percentages of potassium oxid.

In both instances where the manures which contained a quarter ration of each salt were supplemented by an additional three-quarter ration of sodium salt the percentages of sodium oxid in the plant were considerably increased, with but slight or uncertain depression of the potassium oxid. The yield was in one case smaller and in the other larger where the additional sodium salt was employed. These variations were, however, perhaps within the limits of error for such field trials.

In the two instances where the tops were analyzed the sodium oxid and potassium oxid were both found to have been increased in consequence of the employment of a larger amount of sodium salt, yet without an increase in the yield of roots, but on the contrary accompanied by a slightly smaller crop.

No positive benefit to the crop was demonstrated as a result of employing the sodium salts, even when the supply of the potassium salt in the manures was quite limited,* and no evidence was afforded of a conservation of the potassium supply of the soil. On the contrary, the drain upon the potassium of the soil and manures seems to have been somewhat increased in this instance by the employment of the sodium salt.

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* See Bul. 106, May, 1905, page 120.

Below are given the results secured with the carrot:

Carrot, Roots, 1901.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Sodium oxid.	Potassium oxid.
24	Chlorids, limed; ¼ soda, ¼ potash................	315	1.98	1.50
15	Chlorids, limed; 1 soda, ¼ potash................	313	2.54	1.45
48	Carbonates, limed; ¼ soda, ¼ potash.............	315	1.71	1.22
39	Carbonates, limed; 1 soda, ¼ potash.............	306	3.00	1.29
	Carrot, Tops, 1901.			
48	Carbonates, limed; ¼ soda, ¼ potash.............	....	2.17	1.53
39	Carbonates, limed; 1 soda; ¼ potash.............	....	4.76	1.00

The foregoing results on the whole seem to show that, as far as concerned the carrot roots, the employment of an extra three-quarter ration of sodium salt failed to materially affect either the yield or the percentages of potassium oxid in the crop, yet the percentages of sodium oxid in the crop were greatly increased in both instances.

It is of interest to observe that in the case of the tops the use of a greater amount of sodium salt in the manures was accompanied by more than double the amount of sodium oxid in the dry matter, or by a still greater increase than in the case of the roots. At the same time the percentage of potassium oxid in the dry matter of the tops was materially lessened, thus indicating a decided conservation so far as the tops were concerned, which was probably sufficient to insure an economy of potash for the entire plant.

Results Secured with Radishes and Flat Turnips Raised in 1905.

It should perhaps be repeated here that in 1905 each plat received manures as follows:

Pounds per acre.	
1,000	dried blood.
1,500	dissolved bone.
420	magnesium sulfate.

The full rations of potassium and sodium salts were as follows:

Pounds per acre.	
354.9	potassium carbonate.
402.8	muriate of potash.
200.0	sodium chlorid (common salt).
185.0	sodium carbonate (soda ash).

Below are given the results secured with the radish in 1905:

Radish, White Strasburg, 1905.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Sodium oxid.	Potassium oxid.
12	Chlorids, limed once; ¼ soda, ¼ potash...........	398	2.99	3.22
3	Chlorids, limed once; 1 soda, ¼ potash...........	456	4.08	3.17
24	Chlorids, limed thrice; ¼ soda, ¼ potash..........	324	3.50	2.42
15	Chlorids, limed thrice; 1 soda, ¼ potash..........	438	4.44	3.54
36	Carbonates, limed once; ¼ soda, ¼ potash.	372	2.95	2.95
27	Carbonates, limed once; 1 soda, ¼ potash.........	400	4.11	2.58
48	Carbonates, limed thrice; ¼ soda, ¼ potash........	375	2.90	3.21
39	Carbonates, limed thrice; 1 soda, ¼ potash.......	398	4.04	2.60
11	Chlorids, limed once; ¾ soda, ¾ potash...........	557	2.99	6.13
1	Chlorids, limed once; 1 soda, ¾ potash...........	550	3.16	6.34
23	Chlorids, limed thrice; ¾ soda, ¾ potash..........	498	2.85	5.81
13	Chlorids, limed thrice; 1 soda, ¾ potash..........	547	2.66	6.54
35	Carbonates, limed once; ¾ soda, ¾ potash.........	553	2.74	5.03
25	Carbonates, limed once; 1 soda, ¾ potash........	556	2.88	5.52
47	Carbonates, limed thrice; ¾ soda, ¾ potash.......	514	2.75	5.11
37	Carbonates, limed thrice; 1 soda, ¾ potash........	555	2.75	5.43

The addition of a three-quarter ration of sodium salt in all four cases where a quarter ration each of the sodium and potassium salt had already been applied was followed by increased crops. The gains amounted to 14.5, 35.2, 7.5, and 6.1 per cent; the greatest gain having occurred where the chlorids were used upon the land which had already been limed three times. In all four cases the percentage of sodium oxid in the dry matter of the roots was greatly increased when the additional sodium salt was employed in the manures. In one case the percentage of potassium oxid was slightly less, in one case it was about 1 per cent. greater, and in the other two cases it was decidedly less where the extra sodium salt was used. The case of plats Nos. 15 and 24 furnishes a striking exception to the general results and also to those secured in 1899, for the employment of an additional amount of sodium salt was followed in this case by a greater percentage of potassium oxid in the crop.

In all cases where the percentages of potassium oxid were less, in accompaniment with the higher percentages of sodium oxid in the crop and the greater yield, an economy of the potassium had been brought about.

Supplementing the three-quarter rations of the two salts by an extra quarter ration of sodium salt was followed in one case by a decreased yield, too small to have significance, and in three cases by somewhat increased yields, two of which were of sufficient magnitude to be possibly significant. In one of these instances the percentage of sodium oxid was unchanged, in another it was less, and in two other cases it was slightly greater, where the extra sodium salt was added. In all four cases the percentages of potassium oxid in the roots were materially increased where the extra sodium salt had been added to the manures, and yet certainly in some, if not all, cases, without a corresponding advantage to the crop. Taking these results in immediate comparison with those where the initial supply of potassium in the manures was less, it appears (excepting in one of the latter instances) that there was a greater economy of the potassium supply induced by the sodium when the supply of potassium in the manures was limited. Nevertheless, a positive waste of the potassium in the manures occurred when the supply was great. In the latter case the amount of potassium oxid in the dry matter of the plant appears to have probably been in excess of the physiological necessities.

Below is shown the result of adding a half, and in some cases a full, ration of sodium salt to the full ration of potassium salt:

Radish, White Strasburg, Roots, 1905.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Sodium oxid.	Potassium oxid.
10	Chlorids, limed once; 0 soda, 1 potash	522	1.94	6.62
8	Chlorids, limed once; ½ soda, 1 potash	542	2.34	7.72
5	Chlorids, limed once; 1 soda, 1 potash	574	2.73	6.75
22	Chlorids, limed thrice; 0 soda, 1 potash	522	2.02	6.86
20	Chlorids, limed thrice; ½ soda, 1 potash	553	2.66	6.67
34	Carbonates, limed once; 0 soda, 1 potash	548	1.71	6.33
32	Carbonates, limed once; ½ soda, 1 potash	555	2.24	6.19
46	Carbonates, limed thrice; 0 soda, 1 potash	508	2.27	6.05
41	Carbonates, limed thrice; 1 soda, 1 potash	532	2.64	5.32

In every instance the yields were greater where the full ration of potassium salt was supplemented by a half and a full ration of sodium salt. The effect of adding the sodium salt in the manures was in every case to increase the percentage of sodium oxid in the crop in a marked degree. In one of the four cases the percentage of potassium oxid in the crop was increased, and in the other three cases lessened, upon applying the sodium salt. The remarkable results in the case of plats 8 and 10 are in the same direction as those in the case of plats Nos. 15 and 24 (page 247). These results were so exceptional that the analytical work was verified by additional determinations in both cases, yet nevertheless a suspicion might have remained that the samples had been interchanged were it not for the fact that the percentages of sodium determined in the same solutions were in both cases in full agreement with what was to have been expected had no such interchange resulted. Therefore the results indicate that the peculiarities were due to some unknown and obscure factor or factors, rather than to an interchange of samples or to analytical errors.

Turnip, Flat, Roots, 1905.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Sodium oxid	Potassium oxid.
12	Chlorids, limed once; ¼ soda, ¼ potash...........	240	2.14	2.07
3	Chlorids, limed once; 1 soda, ¼ potash...........	373	3.09	1.99
24	Chlorids, limed thrice; ¼ soda, ¼ potash..........	192	2.94	1.79
15	Chlorids, limed thrice; 1 soda, ¼ potash..........	294	3.59	1.96
36	Carbonates, limed once; ¼ soda, ¼ potash.........	227	2.45	1.92
27	Carbonates, limed once; 1 soda, ¼ potash.........	269	3.46	1.68
48	Carbonates, limed thrice; ¼ soda, ¼ potash........	246	2.47	2.03
39	Carbonates, limed thrice; 1 soda, ¼ potash........	372	2.13	2.94
6	Chlorids, limed once; ½ soda, ½ potash...........	390	1.91	2.60
2	Chlorids, limed once; 1 soda, ½ potash...........	402	2.42	3.05
18	Chlorids, limed thrice; ½ soda, ½ potash..........	340	2.30	2.48
14	Chlorids, limed thrice; 1 soda, ½ potash..........	377	2.49	2.72
30	Carbonates, limed once; ½ soda, ½ potash.........	311	2.12	2.29
26	Carbonates, limed once; 1 soda, ½ potash.........	385	2.39	2.48
23	Chlorids, limed thrice; ¾ soda, ¾ potash..........	376	2.09	3.33
13	Chlorids, limed thrice; 1 soda, ¾ potash..........	371	1.70	3.15
47	Carbonates, limed thrice; ¾ soda, ¾ potash........	404	1.72	3.25
37	Carbonates, limed thrice; 1 soda, ¾ potash........	392	1.90	3.22

Turnip, Flat, Roots, 1905.—Concluded.

Plat No.	Special Manures Applied.	Yield, green, pounds.	Per cent. in dry matter.	
			Sodium oxid.	Potassium oxid.
22	Chlorids, limed once; 0 soda, 1 potash	369	1.23	3.69
20	Chlorids, limed once; ½ soda, 1 potash	392	1.38	3.94
17	Chlorids, limed once; 1 soda, 1 potash	382	1.71	3.82
34	Carbonates, limed once; 0 soda, 1 potash	414	1.26	3.53
32	Carbonates, limed once; ½ soda, 1 potash	420	1.47	3.53
29	Carbonates, limed once; 1 soda, 1 potash	358	1.66	3.45
46	Carbonates, limed thrice; 0 soda, 1 potash	384	1.27	3.49
44	Carbonates, limed thrice; ½ soda, 1 potash	399	1.38	3.88
41	Carbonates, limed thrice; 1 soda, 1 potash	394	1.75	3.50

When a quarter ration each of the two salts was supplemented by an additional three-quarter ration of sodium salt, the increase in yield in the four cases amounted to 55, 53, 19, and 51 per cent. In three of the four cases the percentage of sodium oxid in the dry matter of the roots was decidedly increased upon the application of an additional amount of sodium salt in the manures.

In the first and third instances the percentage of potassium oxid in the dry roots was less, and in the second and fourth instances it was greater, where the extra sodium oxid was employed in the manures. These results indicate a conservation of potash, only when the smaller amount of lime was applied.

In the three cases where a half ration of each of the two salts was supplemented by the addition of a half ration of sodium salt the yields all showed an increase, though in one instance it amounted to but about three per cent., or too little to be significant. In all cases the percentages of sodium oxid and of potassium oxid in the dry matter of the roots were increased where the extra sodium salt was applied in the manures. On account of the increase of the potassium percentage accompanying the increase of crop, there would seem to be ground for concluding that the extra potassium might have been the cause of the increase, were it not for the fact that in the case of the crop of plat No. 3 the percentage of potassium oxid was but 1.99, and yet the yield was 373 pounds, or more than in the case of plat No. 18 where the potassium oxid in the dry matter amounted to 2.48 per cent. At all events, in this instance no satisfactory evidence was afforded to show that the presence of the extra sodium salt resulted in effecting an economy of the potassium, at least in so far as concerned the roots.

The addition of an extra quarter ration of the sodium salt to the three-quarter ration of the two salts failed in both cases to increase the crop. In one instance the percentage of sodium oxid in the crop was less and in another greater, and the percentages of potassium oxid in both cases were slightly less, where the extra quarter ration of sodium salt was employed.

The most effective light upon the ability of the sodium salt to conserve the potassium, where the supply of the latter is large, is furnished when full rations of the respective potassium salts were supplemented by half and full rations of the respective sodium salts. These tests in two of the three series indicate slight possible benefit, as concerns yield, in consequence of the presence of the extra sodium salt. In the third series of tests there was one marked exception to this apparent gain. In all three series there was unmistakable evidence of an increased percentage of sodium oxid in the roots where the extra sodium salt was present in the manures. The results as concerns the potassium oxid in the roots were widely variable, but on the whole they give no positive evidence of a conservation of the potassium salt in consequence of the presence of the extra sodium salt.

ADDITIONAL DATA BEARING UPON THE ECONOMICAL UTILIZATION OF PHOSPHORIC ACID, POTASSIUM, AND OTHER SUBSTANCES BY PLANTS AS INFLUENCED BY SODIUM SALTS.

In some instances noted in this chapter the amount of available potassium present was in excess of the needs of the plants, a condition which would exercise a very considerable influence upon the extent of its conservation and upon the relative yields from the plats which are compared. The economic discussions contained herein should only be considered with this fact in mind.

It is of interest to compare the analyses of certain of the crops of white Strasburg radish grown in 1899. Below are the data:

	Plat No. 14. Soda, 1, Potash, ½.	Plat No. 22. Soda, 0, Potash, 1.
Yield (in pounds)	766	709
In Dry Matter.	*Per cent.*	*Per cent.*
Phosphoric acid	0.90	0.78
Potassium oxid	5.19	8.43
Sodium oxid	5.12	2.02
Calcium oxid	1.32	1.46
Magnesium oxid,	0.63	0.89

From the foregoing it will be seen that when the full ration of potassium salt was used, which amount was in excess of the plant needs, the yield was actually less than when a half ration of potassium supplemented by a full ration of sodium was employed. It will be observed that the percentage of phosphoric acid was greater in the latter than in the former case, but that the amounts of potassium oxid, calcium oxid, and magnesium oxid per hundred pounds of dry matter were all greater when the full ration of potassium was applied. A much greater amount of sodium oxid was, however, removed where the sodium salt was added in the manures. The extra loss of sodium oxid from the removal of the crop was, however, but 3.10 pounds per hundred pounds of dry matter when the sodium was present in the manures, while on the other hand the loss of potassium oxid was 3.24 pounds for every hundred pounds of dry matter in the case where the sodium salt was omitted from the manures. In view of the sodium costing practically nothing if bought in nitrate of soda, kainit, and muriate of potash, the saving in potassium from its use was far more than enough to offset the losses in other ingredients.

If it should be shown that the value of the product for nutrient purposes is greater when the per cent. of phosphorus is increased, the economy resulting from the presence of the sodium salt would then be found to be still more enhanced.

It should be observed that the liming having been identical and chlorids having been applied in the case of both of the plats cited above, the results in that respect are strictly comparable.

A comparison similar to the one given above is rendered possible by data from the same crop and year in the limed carbonate series.

Below are the data to which reference is made:

	Plat No. 38. Soda, 1, Potash, ½.	Plat No. 46. Soda, 0, Potash, 1.
Yield (in pounds)	662	655
In Dry Matter.	*Per cent.*	*Per cent.*
Phosphoric acid	1.10	0.96
Potassium oxid	5.27	9.82
Sodium oxid	5.72	1.43
Calcium oxid	1.17	1.61
Magnesium oxid	0.67	1.10

The amounts of phosphoric acid and of sodium oxid in the dry matter were, as before, greater when the sodium salt was employed. The additional sodium oxid removed per hundred pounds of dry matter, when the sodium salt was added to the manures, amounted to 4.29 pounds, and the similar loss of extra potassium oxid when the full ration of potassium salt was used without supplemental sodium salt amounted to 4.55 pounds. This is sufficient to show in this case that the sodium salt even at current prices would have effected an economy so far as concerned the conservation of plant food removed by the radish roots, and when it is borne in mind that the sodium could have been secured in nitrate of soda or in certain of the German potash salts practically free of cost, the bearing of this feature of these results becomes even more significant.

Below are given data secured with the flat turnip in the same year:

	Plat No. 15. Soda, 1, Potash, ¼.	Plat No. 22. Soda, 0, Potash, 1.
Yield (in pounds)	293	234
In Dry Matter.	*Per cent.*	*Per cent.*
Phosphoric acid	1.26	1.03
Potassium oxid	2.13	4.54
Sodium oxid	5.05	1.46
Calcium oxid	1.26	1.31
Magnesium oxid	0.69	0.62

In this instance the yield was greater when the quarter ration of potassium salt was supplemented by a full ration of sodium salt than when a full ration of potassium salt was used without any sodium salt whatsoever.

It will be seen that, as in the case of the radish, the use of the sodium salt raised the percentages of sodium oxid and of phosphoric acid in the dry matter of the roots, but, unlike the previous instances, the use of the sodium salt slightly increased rather than lessened the magnesium oxid removed.

The extra amount of sodium oxid removed per hundred pounds of dry matter when the sodium salt was added in the manures, amounted to 3.59 pounds; and the extra quantity of potassium oxid removed per hundred pounds of dry matter when the sodium salt was omitted and a full ration of potassium salt was used in the manures, amounted to 2.41 pounds. The conservation of the potassium salt by virtue of employing the sodium salt was great, though not so striking as in the case of the radish.

The following are results with the Norbiton Giant beet (mangel-wurzel):

	Plat No. 15. Soda, 1, Potash, ½.	Plat No. 22 Soda, 0, Potash, 1.
Yield (in pounds)	682	689
In Dry Matter.	*Per cent.*	*Per cent.*
Phosphoric acid	0.32	0.33
Potassium oxid	0.84	3.65
Sodium oxid	4.63	1.71
Calcium oxid	0.26	0.26
Magnesium oxid	0.50	0.51

In this case the percentages of phosphoric acid, calcium oxid, and magnesium oxid are practically the same.

When the sodium salt was used the extra quantity of sodium oxid removed in the roots amounted to 2.92 pounds per hundred of dry matter, and when the full ration of potassium salt was employed without the sodium salt the extra amount of potassium removed per hundred of dry matter was 2.81 pounds.

Still another comparison of results with the same beet is possible in the limed carbonate series. The results are as follows:

	Plat No. 39. Soda, 1, Potash, ½.	Plat No. 46. Soda, 0, Potash, 1.
Yield (in pounds)	601	797
In Dry Matter.	*Per cent.*	*Per cent.*
Phosphoric acid	0.39	0.35
Potassium oxid	0.81	3.69
Sodium oxid	5.10	1.06
Calcium oxid	0.29	0.27
Magnesium oxid	0.48	0.47

This is the first instance discussed in this particular connection in which the yield has been decidedly greater where the full ration of potassium was employed without any supplementary sodium salt. It will be seen that far less potassium oxid was removed in the crop when the sodium salt was applied in the manures but the lessened yield may have been enough to fully offset this apparent saving.

It is of interest to observe that the sodium salt applied in the manures did not materially change the percentages of phosphoric acid, calcium oxid, and magnesium oxid.

Below are the data secured with chicory, in the limed chlorid series (crop of 1899):

	Plat No. 15. Soda, 1, Potash, ¼.	Plat No. 22. Soda, 0, Potash, 1.
Yield (in pounds)	189	312
In Dry Matter.	*Per cent.*	*Per cent.*
Phosphoric acid	0.48	0.45
Potassium oxid	0.62	1.42
Sodium oxid	1.01	0.37
Calcium oxid	0.24	0.22
Magnesium oxid	0.25	0.18

In this case the substitution of a full ration of sodium salt for a three-quarter ration of potassium salt resulted in a smaller yield and in an increase of sodium oxid in the dry matter from 0.37 to 1.01 per cent. At the same time there was an increase in the percentages of phosphoric acid, calcium oxid, and magnesium oxid. The percentage of potassium oxid, on the contrary, was depressed from 1.42 to 0.62. In this case, as in that of the last-mentioned results with beets, the depression of the yield probably far more than offsets the conservation of the potassium in the soil.

Still another comparison is rendered possible with chicory roots in the same year, in the limed carbonate series. The results are given below:

	Plat No. 39. Soda, 1, Potash, ¼.	Plat No. 46. Soda, 0, Potash, 1.
Yield (in pounds)	205	256
In Dry Matter.	*Per cent.*	*Per cent.*
Phosphoric acid	0.59	0.46
Potassium oxid	0.37	1.43
Sodium oxid	1.04	0.35
Calcium oxid	0.26	0.24
Magnesium oxid	0.32	0.18

In this instance, as in the preceding one, cutting down the potassium salt to a quarter ration and adding in its place a full ration of the sodium salt raised the percentages in dry matter of all of the ingredients excepting potassium oxid, which was depressed from 1.43 to 0.37 per cent. In view of the reduction in yield and the increased drain on the other mineral elements, it does not seem to have been an advantageous proceeding to substitute the sodium salt for the potassium salt in the manures even notwithstanding that less potassium oxid was withdrawn from the soil in each one hundred pounds of dry roots.

The results secured with the flat turnip roots in 1905 render possible certain comparisons which throw light upon the conservation of potassium in consequence of using sodium salts in the manures. All of the results used in this comparison were from the chlorid series which had been limed once. The results are as follows:

	Plat No. 2. Soda, 1, Potash, ½.	Plat No. 6. Soda, ½, Potash, ½.	Plat No. 10. Soda, 0, Potash, 1.
Yield (in pounds)	402	390	417
In Dry Matter.	*Per cent.*	*Per cent.*	*Per cent.*
Nitrogen	2.80	2.41	2.37
Phosphoric acid	1.42	1.29	1.33
Potassium oxid	3.05	2.60	3.93
Sodium oxid	2.42	1.91	1.04
Calcium oxid	0.80	0.83	0.80
Magnesium oxid	0.35	0.37	0.47

In this case the yields were but slightly less where a half ration of each salt was used and where a half ration of potassium salt was supplemented by a full ration of sodium salt, than where the full ration of potassium salt was employed.

In the instance of a half ration of each (plat No. 6) a depression of the magnesium oxid, phosphoric acid, and potassium oxid resulted. The percentage in the dry matter dropped in the latter case from 3.93 to 2.60. When a further half ration of sodium salt was added (plat No. 2), even more nitrogen was removed than in either of the other cases and the conservation of the potassium was less than before, which factor, added to the cost of the additional half ration of sodium salt, also leaves one disinclined to believe that any actual net benefit resulted from its addition. It is of course possible in the last instance

PLANT GROWTH AS INFLUENCED BY THE EFFECT OF SODIUM UPON OSMOTIC PRESSURE.

It seems to have been satisfactorily established that there may be circumstances under which the addition of common salt or of other soluble salts to solutions aids the growth of plants solely by virtue of increasing the osmotic pressure. In how far one may speculate upon such benefit when the addition is made directly to the soil, is a question that may well be considered open for discussion. It may readily be seen that owing to the fixing or absorbing power of soils it is not safe to expect that salts applied to the soil will have the same effect as when applied in solution, or that the effect will be lasting in its character. Water-culture investigations are now in progress to attempt to ascertain if the sodium salts were probably beneficial on this account.

CONCERNING POSSIBLE PHYSIOLOGICAL FUNCTIONS OF SODIUM.

It appears to be so universally conceded that sodium can not fully replace potassium in its physiological functions in connection with the growth of agricultural plants that it seems wholly unnecessary to make an array of the high authorities in practically every civilized land to that effect. It is of interest to observe that most of those who have written upon this subject seem to assume that potassium has but one physiological function, namely, that of aiding in the formation and translocation of starch. Benecke* suggests that sodium may aid in maintaining the turgor of plants by the performance of osmotic service in the place of potassium. Concerning potassium in its relation to turgor, Copeland† says that it is a factor, direct or indirect, in maintaining the turgor of the plant, and that when phosphorus, magnesium, and sulfur were omitted there was poor growth but high turgor; but that in the absence of potassium the growth was stunted and the turgor decreased. In this connection it may be mentioned that De Vries* held for some time that organic acids were of primary importance in maintaining turgor, a position from which he receded later.† It seems to be held that growth may occur without turgor and that unusually rapid growth may lessen it. According to Pfeffer, turgor can not supply the energy necessary for growth, hence it is rather a result of the conditions of, than itself a cause of, growth; hence Pfeffer considers turgidity as only of accessory importance.

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*Ein Beitrag. zur. mineralischen Nahrung der Pflanzen, Ber. Deut. Bot. Gesell. 12 (1894), General Versammlung, p. 114. Quoted from Copeland.

†Bot. Gaz. 24 (1897), p. 411.

Concerning the association of potassium, only with the function of aiding in the formation and translocation of carbohydrates, Pfeffer‡ holds that phosphorus may be as essential as potassium, and he adds that "the function of an essential element is by no means directly indicated by the result which its absence produces." In this connection attention should be called to the fact that sodium has been found, in the course of our own experiments, to have been a carrier of phosphorus to the plant.

In some cases, according to Goodale,§ sodium may be substituted for a part of the potassium which would otherwise be needed by the plant.

Mention is made by A. Mayer of the free movement of sodium salts in the plant, and he suggests that the sodium may combine with organic acids, without having special physiological significance, on the ground that it makes no difference to the plant what particular metal is thus combined. At this point it is of interest to call attention to the experiments by Mercadante,|| who grew species of *Oxalis* and *Rumex* without potassium. As a result neither flowers nor fruit were formed, and only one-eighth of the normal amount of acid was present. The oxalic and tartaric acids which were produced were found in combination with lime, and only small amounts of sugar and starch were found in the sap of the plant. It is known that under normal conditions of growth the organic acids which are said to be

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*Bot. Ztg. 1879, p. 848.

†Pfeffer: The Physiology of Plants. Translated by Ewart (1900), Vol. I, p. 141.

‡Ibid, Vol. 1, p. 424.

§Physiological Botany (1885), p. 255.

||Abs. Jahresber. Agr. Chemie, 8, p. 257.

formed in the process of the synthesis of the proteids* are often found combined in part with potassium. It is also asserted by Schimper† that the neutral, and more especially the acid, salts of potassium and oxalic acid which may result if lime is lacking, are themselves poisonous; nevertheless it may be necessary that oxalic acid combine at first with a base like sodium or potassium while being transported to other parts of the plant where it can be precipitated out as oxalate of lime, whereby it ceases to interfere with the physiological functions. In other words, the presence of oxalates of the alkalis in small amounts may be essential to the welfare of the plant, even though in large quantities they may be inimical to its growth. Whether in the absence of sufficient potassium, sodium may be of use merely to combine with and aid in the disposal of organic acids in the plant, is a point which it might if possible be of interest to determine.

From water-culture experiments with maize, Stohmann‡ concluded that sodium was an element essential to its perfect development. It is held by Müntz and Girard§ that if soda is ever essential to plants it may be in connection with the mangel-wurzel. Sodium, according to Aikman,|| is possibly essential to plants in minute quantities; and A. Mayer,** though he believes that for certain plants soda may not be essential, warns against making a general deduction to this effect, since he thinks that the large amount of sodium in certain plants may be a hint that they require it or are in some way benefited by it.

It is held by Salm-Horstmar†† that for wheat and oats, sodium is advantageous, but that it is necessary only for the perfection of the seed. According to Johnson,‡‡ if sodium is indispensable, only minute quantities are necessary to plants.

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*Schimper; Zur Frage der Assimilation der Mineralsalze durch die gruene Pflanze.

†Flora (1890), pp. 207–261.

‡Jour. Landw. (1862), p. 25.

§Les Engrais, Vol. 3, p. 153.

||Manures and the Principles of Manuring (1894), p. 55.

**Lehrbuch der Agrikulturchemie I (1895), p. 283.

††Versuche und Resultate ueber die Nahrung d. Pflanzen Braunschweig (1856), pp. 12, 27, 29, and 36.

‡‡How Plants Grow (1891), p. 189.

More recently Atterberg* conducted experiments in quartz sand in which he substituted in one case calcium and in the other sodium for a part of the potassium, with the result that the yields fell off in a far greater degree when calcium was substituted than when he used the sodium. From this work he drew the conclusion that sodium was by no means a useless ingredient in manures, but that when the supply of potassium is limited it may perform a very useful function in connection with plant growth. The following year Wagner and Dorsch† also made strong claims for the direct manurial action of sodium, asserting that when the supply of potassium was limited to a small amount, the employment of sodium in its capacity as a *direct* manure increased the crop one-half.

Following shortly after the publication of these results by Atterberg, and Wagner and Dorsch, Stahl-Schroeder‡ published certain researches which seemed to contradict their work. In this connection the claim was made that the media in which the plants were grown by Atterberg, and Wagner and Dorsch, doubtless contained potassium which was liberated upon the application of sodium salts; and that the sodium had not acted as a direct manure. Thus he essayed to show that the conclusion of these experimenters was utterly faulty. The matter was of so much interest, in view of the fact that Atterberg was reported to have used "pure silica" in which to conduct his experiments, that one of us (H. J. W.) wrote to him asking if the silica in which the plants were grown was actually analyzed, and if so, what percentages of both sodium and potassium were really present. In response to this inquiry it was stated that a surprising amount of sodium was found in the crop in certain cases where it was not to be expected, and he stated that it evidently came from the sand, which was found to contain sodium chlorid. Furthermore, the asphalt paint which was applied to the interior of the pots contained considerable quantities of some mineral matter. It was not stated, however, whether or not the silica and paint were tested for potassium, hence it is reasonable to infer, in view of the presence of such considerable amounts of sodium, that potassium may have been present and may have been set free by the sodium salts which were employed. It is greatly to be hoped, therefore, that Prof. Atterberg will repeat his experiments with a medium demonstrated at the outset to be free from potassium.

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*Deut. Landw. Presse (1891), p. 1035.

†Die Stickstoffdüngung d. landw. Kulturpflanzen (1892), pp. 227–242.

‡Jour. Landw. 47 (1899), pp. 49–84.

Still more recently Pfeiffer* and his co-workers have been studying the action of sodium salts in connection with barley, and as a result of their investigations and critical study of the experiments by Hellriegel and Wilfarth, and also by Doll and others, they have arrived at the conclusion that, aside from the action of sodium salts in liberating potash in the soil, they also replace some of the potash in the leaves and stalks, in consequence of which more potash is at the disposal of the plant to use in the formation of the seed. Such benefit would of course only be expected in cases where there exists an actual shortage of potassium. In their own experiments little evidence was afforded of an actual replacement of potassium by sodium in the seed itself to the advantage of the plant, yet they cite experiments by Doll, Hellriegal, and Wilfarth which seem to them to justify the view that benefit, even in that direction, may result.

During the summer of 1905 Breazeale,† while engaged in co-operative experiments between the Bureau of Soils of the U. S. Department of Agriculture and this Station, undertook experiments which suggested themselves to him after a study of our own pot and field work, and found that plants which had been grown for a time in a solution containing sodium, took up far less potassium when transferred to a full nutrient solution, than those which had been kept under the same conditions and for the same length of time in a solution from which sodium was excluded. From this the inference might be drawn, particularly in view of the better growth and transpiration during the preliminary and final stages in those cases where the sodium salt was used at the outset, that the sodium had lessened

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*Mitt. Landw. Inst., Breslau (1905). pp. 567–613.
†Jour. Amer. Chem. Soc. 28, p. 1013.

the requirements for potassium and that therefore some physiological function was probably to be attributed to the sodium salt.

Pember, of the Bureau of Soils of the U. S. Department of Agriculture, and Hartwell are at the present time engaged in similar co-operative work making water-culture tests as suggested by two of us (H. J. W. and B. L. H.). The results thus far obtained are given below.

In experiment I, where both a one-fourth and a one-eighth "ration" of the potassium salt was supplemented by the calcium salt, the transpiration and green weights were both lessened, and by the addition of the sodium salt both were decidedly increased.

In experiment II the results were somewhat unsatisfactory owing to the prevailing climatic conditions; the results, however, when only a one-eighth ration of potassium was used, agree with those in experiment I, excepting for the low transpiration when the extra seven-eighth ration of the sodium salt was used. In other words, in this case the green weight was materially increased by using the sodium salt, notwithstanding that the transpiration figures failed to point in the same direction. The addition of the calcium salt to the one-eighth ration of potassium salt appeared both by transpiration and green weight to have been beneficial, but in a far less degree than the added sodium.

In experiment III the addition of the calcium apparently increased the transpiration and green weights more or less in both cases, but in a far less degree, with one exception, than the sodium.

In experiment IV with a one-eighth ration of potassium the calcium seemed to be beneficial as far as concerned the green weight, but in both cases the results with sodium were far superior to those with extra calcium. When a one-fourth ration of potassium was used the transpiration and yields were smaller in both cases upon the employment of the extra calcium salt, but both were increased by the addition of the sodium salt.

In experiment Va and Vb, excepting the smaller green weight in series Va, the use of the additional calcium salt was followed by gains in both transpiration and green weight, while a most marked gain in both resulted when the sodium salt was added.

The amounts of total solids were the same in all cases in a given experiment, excepting where only a one-eighth or a one-fourth ration of potassium was applied. If it were argued that the difference in the osmotic pressure produced by the calcium and the sodium accounted for the greater gain from the latter, it would be expected that the calcium would have proved helpful in all cases and far more so than in most of the instances. Furthermore, increased amounts of the calcium and sodium salts have been added to the potash ration in other series of experiments now in progress, but without certain increased benefit, a fact which leads one to infer that the great benefit observed from the sodium in this instance can not have been wholly or even largely due to influencing the osmotic pressure. It will be observed that these culture experiments were conducted in solutions, thus eliminating indirect manurial action; hence there seems no escape from the conclusion that the benefit must have been physiological in character, particularly when it is stated that less potash was frequently removed from the solution when sodium was added than when it was not. It is proposed, nevertheless, to pay particular attention, if feasible, in future experiments to the possibility of differences in the chemical reaction of the solutions when the soda is employed and when it is not used, yet it appears hardly probable that this will serve to explain the differences in results. It is desirable that it be ascertained, if possible, whether the good effect of the sodium salts in water culture can have been due to changing in a beneficial way the relationships of lime and magnesia and possibly other mineral plant ingredients.

It is mentioned by Schneidewind* that Hellriegel and Wilfarth produced, with more soda and less potash, the same amount of dry matter and sugar as where a larger quantity of potash was employed; nevertheless he believes that the advantage of soda which he has frequently observed in his experiments with beets was due primarily not to physiological functions but rather to the greater solubility of the sodium than of the potassium salts of nitric, phosphoric, and sulphuric acids, on account of which they more readily entered the plants.

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*Jour. Landw. (1898), p. 7, 8.

S. Suzuki* calls attention to an interesting possibility concerning sodium in plants, for he recalls the work of Chittenden showing that the efficiency of vegetable diastase is increased by small amounts (0.24 per cent.) of sodium chlorid, just as has been shown by Wachsmann† to be the case with animal diastase. He also cites that A. Mayer‡ found that a 1 per cent. solution of potassium chlorid retarded diastatic action, while smaller quantities exerted no decisive result. Hence Suzuki suggests a physiological function of sodium chlorid in plant growth by virtue of its possibly acting with diastase in the transport of starch to the growing tips of plants, thus explaining the function in connection with starch in an indirect rather than in a direct way.

It seems by all means desirable that far more definite knowledge should be gained concerning the functions of sodium than that which we now possess, and furthermore it should be definitely ascertained what varieties of plants are most likely to be benefited by sodium salts when there is a lack of potassium salts. Such information will place the farmer in far better position to know when to employ advantageously manures rich in sodium salts, such as nitrate of soda and kainit, as a sort of insurance against a depression of yield on account of a deficiency of potash. Furthermore, the conditions under which sodium salts may conserve the potash stores within the soil should be thoroughly studied, and it should be ascertained with what agricultural plants such a conservation of potash is possible, or, in other words, what plants may be prevented from overfeeding on potash if provided with soda.

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*Bul. Col. Agr. Tokio, Imp. Univ. 6 (1905), No. 4. p. 408.

†Pflueger's Archiv. 91 (1902), p. 191.

‡Jour. f. Landw. 49, p. 57.

SUMMARY.

These experiments show that in the presence of very limited supplies of potassium salts, sodium salts may greatly increase the yields of certain crops.

In the case of the mangel-wurzel, similar benefit from sodium salts occurred when as much as 332 pounds of muriate of potash, or its equivalent of potassium carbonate, were employed per acre. Also, in connection with certain other plants, similar, though less marked, benefit from sodium salts was observed even when the applications of potassium salt were large.

Sodium salts were found to increase the percentage of phosphorus in the plant. In this respect the carbonate was more efficient than the chlorid. The results furnish much evidence to show that this was an incidental accompaniment of the employment of the sodium salts rather than the cause of the increased growth which resulted. This feature should nevertheless be further investigated.

Little evidence was secured to indicate that the benefit to plant growth caused by the sodium salts was due to changing the ratio of lime and magnesia in the plants.

The sodium salts undoubtedly acted as indirect manures by virtue of liberating potash, yet strong evidence was afforded that the potassium taken up by the plant was often more economically utilized, or in other words a greater crop was produced, when sodium salts were applied in the manures and when relatively more sodium entered the plant.

The water-culture investigations show unquestionable benefit, under certain conditions, from the employment of sodium salts in the presence of limited supplies of potassium, which is not attributable to liberation of plant food, effect upon soil moisture, etc. This benefit does not seem to be wholly or chiefly explainable upon the ground that the sodium salts had increased the osmotic pressure, for calcium salts failed to have the same marked effect.

In the dry season of 1899 strong evidence was afforded that applications of sodium salts to the soil prevented the plants from taking up and removing unnecessary amounts of potash, or in other words the sodium seemed to conserve the potassium of the soil. In the wet season of 1901 the contrary apparently resulted. This indicates the necessity of a more careful study of the conditions affecting the beneficial action of sodium salts and the danger of drawing definite and final conclusions from a single experiment.

The results do not indicate that it would be wise to purposely cut down the supplies of potassium enough to make sodium salts beneficial, for fear of depressing the crops, nor to buy common salt nor sodium carbonate for the purpose of attempting to conserve the potassium in the soil; yet the sodium in the potash salts and in nitrate of soda, which practically costs nothing, may often increase certain crops if a shortage of potassium occurs.

The results go to show that the beneficial influence of sodium salts is largely conditioned upon the variety of plant, and this is a field of investigation that has as yet remained grossly neglected, not only in this country but also in Europe.

It is proposed to further study the influence of sodium salts upon the reaction of the medium and the bearing of this influence upon the growth of plants, also the possible influence of the sodium in changing the ratio of other mineral ingredients taken from solutions by growing plants. In short, it is hoped by these and other means to throw additional light upon the physiological functions of sodium and the practical significance of sodium salts in agriculture.

A study has been begun of the influence of the application of varying proportions of sodium and potassium salts upon the organic constituents of certain plants.

APPENDIX.

A COMPLETE COMPILATION OF THE ANALYTICAL PERCENTAGE DATA IN THE FOREGOING DISCUSSION.

GOLDEN MILLET, 1898.

	Unlimed Carbonates.		Limed Carbonates.	
Soda ration	1	¼	1	¼
Potash ration	¼	¼	¼	¼
Plat No.	**27**	**36**	**39**	**48**
Crude ash	9.18	7.75	8.97	8.62
Silica and insol. matter	4.76	3.80	3.77	3.03
Phosphoric acid	.79	.63	.71	....
Sulfuric acid	.53	.53	.35	.48
Potassium oxid	.97	1.09	1.09	1.16
Sodium oxid	.17	.14	.07	.05
Calcium oxid	....	....	.88	....
Ferric and aluminic oxids	.21	.18	.14	....
Yield, green, pounds	102	132	155	142

WHITE STRASBURG RADISH (ROOTS), 1899.

	Unlimed Chlorids.			
Soda ration	1	½	1	¼
Potash ration	½	½	¼	¼
Plat No.	**2**	**6**	**8**	**12**
Nitrogen	3.31	3.19	3.68	3.42
Crude ash	23.22	20.87	22.49	17.51
Silica and insol. matter	....	.11	.12	.15
Phosphoric acid	1.02	.98	1.13	1.02
Potassium oxid	6.72	6.12	3.76	3.69
Sodium oxid	4.14	3.67	6.38	3.83
Calcium oxid	1.06	1.02	1.09	1.38
Magnesium oxid	.58	.65	.67	.73
Yield, green, pounds	834	797	709	547

WHITE STRASBURG RADISH (ROOTS), 1899.

	Limed Chlorids.				
Soda ration	1	½	1	¼	0
Potash ration	½	½	¼	¼	1
Plat No	**14**	**18**	**15**	**24**	**23**
Nitrogen	3.71	3.74	3.54	3.53	....
Pure ash and insol. matter	....	....	16.11	14.47	17.74
Crude ash	24.14	20.35	....	....	....
Silica and insol. matter	.17	.12	.16	.29	.17
Carbon dioxid	....	....	3.29	3.32	3.78
Phosphoric acid	.90	.84	.98	.89	.78
Sulfuric acid	....	....	1.96	1.84	....
Potassium oxid	5.19	5.54	2.85	3.62	8.43
Sodium oxid	5.12	3.62	6.01	4.03	2.02
Calcium oxid	1.32	1.43	1.19	1.56	1.46
Magnesium oxid	.63	.56	.73	1.02	.89
Yield, green, pounds	766	662	685	432	709

WHITE STRASBURG RADISH (ROOTS), 1899.

	Unlimed Carbonates.			
Soda ration	1	½	1	¼
Potash ration	½	½	¼	¼
Plat No	**26**	**30**	**29**	**36**
Nitrogen	3.80	3.47	3.74	3.33
Crude ash	22.63	20.47	21.49	17.33
Silica and insol. matter	.07	.05	.08	.11
Phosphoric acid	1.13	1.05	1.13	.99
Potassium oxid	4.98	5.59	2.90	3.05
Sodium oxid	4.50	3.60	6.57	3.56
Calcium oxid	1.23	1.24	1.27	1.17
Magnesium oxid	.90	.75	.94	.77
Yield, green, pounds	817	776	722	547

WHITE STRASBURG RADISH (ROOTS), 1899.

	Limed Carbonates.				
Soda ration	1	½	1	¼	0
Potash ration	½	½	¼	¼	1
Plat No	**38**	**42**	**39**	**48**	**46**
Nitrogen	3.85	3.59	3.60	3.77	....
Pure ash and insol. matter	....	....	15.33	13.88	18.10
Crude ash	28.40	22.54	....	....	....
Carbon dioxid	....	....	4.54	3.38	5.05
Phosphoric acid	1.10	1.05	1.08	.96	.96
Sulfuric acid	....	....	2.35	1.97	....
Potassium oxid	5.27	5.48	2.81	3.61	9.82
Sodium oxid	5.72	4.07	6.50	3.69	1.43
Calcium oxid	1.17	1.19	1.07	1.53	1.61
Magnesium oxid	.67	.72	.76	1.17	1.10
Yield, green, pounds	662	621	540	432	655

FLAT TURNIP (ROOTS), 1899.

	Limed Chlorids.			Unlimed Carbonates.	
Soda ration	1	¼	0	1	¼
Potash ration	¼	¼	1	¼	¼
Plat No	**15**	**24**	**33**	**27**	**36**
Nitrogen	....	....	....	3.92	4.19
Pure ash and insol. matter	15.27	11.46	13.24	....	....
Silica and insol. matter	1.44	.91	1.37	.75	1.38
Carbon dioxid	2.52	1.88	1.90	....	....
Phosphoric acid	1.26	.98	1.03	.89	1.00
Sulfuric acid	1.95	1.60	....	....	....
Potassium oxid	2.13	2.88	4.54	3.21	2.54
Sodium oxid	5.05	2.37	1.46	2.31	2.88
Calcium oxid	1.26	1.32	1.31	1.36	1.45
Magnesium oxid	.69	.60	.62	.64	.69
Yield, green, pounds	293	214	234	212	149

NORBITON GIANT BEET (ROOTS), 1899.

	Limed Chlorids.			Limed Carbonates.		
Soda ration	1	½	0	1	½	0
Potash ration	¼	¼	1	¼	¼	1
Plat No	**15**	**24**	**22**	**39**	**48**	**46**
Nitrogen	1.75	1.63	....	2.20	2.23	....
Pure ash and insol. matter	8.81	6.27	8.61	8.92	7.00	7.07
Silica and insol. matter	....	....	.49	....	....	.56
Carbon dioxid	2.08	1.63	1.99	3.33	2.31	2.47
Phosphoric acid	.32	.24	.33	.39	.37	.35
Sulfuric acid	.31	.30	....	.40	.39	....
Potassium oxid	.84	1.24	3.65	.81	1.10	3.69
Sodium oxid	4.63	2.65	1.71	5.10	2.92	1.06
Calcium oxid	.26	.24	.26	.29	.25	.27
Magnesium oxid	.50	.56	.51	.48	.74	.47
Ferric and aluminic oxid	.10	.12	....	.14	.15	....
Yield, green, pounds	682	421	689	601	299	797

CARROT (ROOTS), 1899.

	Limed Chlorids.		Limed Carbonates.	
Soda ration	1	½	1	½
Potash ration	¼	¼	¼	¼
Plat No	**15**	**24**	**39**	**48**
Nitrogen	2.73	2.58	2.93	3.02
Crude ash	....	....	12.14	11.77
Silica and insol. matter	.51	.50	.57	.41
Phosphoric acid	1.20	1.03	1.09	1.07
Potassium oxid	2.11	2.09	1.30	2.36
Sodium oxid	3.77	3.00	3.88	2.89
Calcium oxid	.74	.78	.68	.70
Magnesium oxid	.32	.39	.35	.41
Yield, green, pounds	483	343	483	373

CHICORY (ROOTS), 1899.

	Limed Chlorids.			Limed Carbonates.		
Soda ration	1	½	0	1	½	0
Potash ration	¼	¼	1	¼	¼	1
Plat No	**15**	**24**	**22**	**39**	**48**	**46**
Pure ash and insol. matter	3.49	2.99	3.47	3.21	3.13	3.32
Silica and insol. matter	.26	.28	.27	.18	.28	.23
Carbon dioxid	.50	.33	.55	.50	.35	.72
Phosphoric acid	.48	.49	.45	.59	.56	.46
Sulfuric acid	.20	.23	....	.25	.28	....
Potassium oxid	.62	.48	1.42	.37	.45	1.43
Sodium oxid	1.01	.80	.37	1.04	.81	.35
Calcium oxid	.24	.22	.22	.26	.25	.24
Magnesium oxid	.25	.25	.18	.32	.32	.18
Ferric and aluminic oxids	.06	.06	....	.04	.04	....
Yield, green, pounds	189	200	312	205	234	256

WHITE STRASBURG RADISH (ROOTS), 1901.

	Unlimed Chlorids.	
Soda ration	1	½
Potash ration	¼	¼
Plat No	**3**	**12**
Nitrogen	3.20	3.54
Crude ash	19.65	18.53
Silica and insol. matter	.30	.21
Phosphoric acid	1.08	1.08
Potassium oxid	6.03	5.42
Sodium oxid	3.55	3.09
Calcium oxid	.90	1.13
Magnesium oxid	.53	.65
Yield, green, pounds	216	234

WHITE STRASBURG RADISH (ROOTS), 1901.

	Limed Chlorids.		
Soda ration	¾	½	0
Potash ration	1	1	1
Plat No	**19**	**20**	**22**
Phosphoric acid	1.06	1.09	1.03
Potassium oxid	11.05	9.81	9.41
Sodium oxid	1.40	1.95	1.43
Calcium oxid	1.00	1.13	1.10
Magnesium oxid	.53	.66	.64
Yield, green, pounds	243	261	248

WHITE STRASBURG RADISH (ROOTS), 1901.

	Unlimed Carbonates.		
Soda ration	¾	½	0
Potash ration	1	1	1
Plat No	**31**	**32**	**34**
Phosphoric acid	1.12	1.15	1.09
Potassium oxid	11.55	10.73	10.66
Sodium oxid	1.65	1.52	.91
Calcium oxid	.84	.95	.96
Magnesium oxid	.50	.59	.57
Yield, green, pounds	279	291	288

WHITE STRASBURG RADISH (ROOTS), 1901.

	Limed Carbonates.		
Soda ration	¾	½	0
Potash ration	1	1	1
Plat No	**43**	**44**	**46**
Phosphoric acid	1.09	1.00	.92
Potassium oxid	10.00	9.21	9.42
Sodium oxid	1.60	1.56	.97
Calcium oxid	.89	.86	1.08
Magnesium oxid	.57	.51	.58
Yield, green, pounds	243	252	228

CHICORY (ROOTS). 1901.

	[Limed Chlorids.		Limed Carbonates.	
Soda ration	1	¼	1	¼
Potash ration	¼	¼	¼	¼
Plat No	**15**	**24**	**39**	**48**
Nitrogen	1.12	1.03	1.19	1.14
Pure ash and insoluble matter	3.33	2.95	2.82	3.01
Carbon dioxid	.50	.46	.91	.41
Phosphoric acid	.53	.43	.48	.49
Sulfuric acid	.21	.22	.23	.24
Potassium oxid	.62	.63	.50	.55
Sodium oxid	1.18	.96	1.19	.84
Calcium oxid	.23	.22	.24	.21
Magnesium oxid	.24	.24	.27	.26
Yield, green, pounds	225	194	117	113

CHICORY (ROOTS), 1901.

	Limed Chlorids.		
Soda ration	¾	½	0
Potash ration	1	1	1
Plat No	**19**	**20**	**22**
Phosphoric acid	.44	.42	.43
Potassium oxid	1.97	1.90	1.82
Sodium oxid	.52	.72	.67
Calcium oxid	.24	.24	.24
Magnesium oxid	.16	.17	.17
Yield, green, pounds	243	243	243

CHICORY (ROOTS), 1901.

	Unlimed Carbonates.		
Soda ration	¾	½	0
Potash ration	1	1	1
Plat No	**31**	**32**	**34**
Nitrogen	.96	.95	.95
Phosphoric acid	.40	.41	.39
Potassium oxid	2.16	1.89	2.02
Sodium oxid	.52	.51	.34
Calcium oxid	.24	.24	.23
Magnesium oxid	.16	.15	.17
Yield, green, pounds	194	180	162

CHICORY (TOPS), 1901.

	Limed Carbonates.	
Soda ration	1	¼
Potash ration	¼	¼
Plat No	**39**	**48**
Crude ash	13.79	13.14
Silica and insol. matter	.77	.76
Phosphoric acid	.56	.51
Potassium oxid	.97	.76
Sodium oxid	3.84	2.29
Calcium oxid	2.22	2.71
Magnesium oxid	1.11	1.81

CARROT (ROOTS), 1901.

	Limed Chlorids.		Limed Carbonates.	
Soda ration	1	¼	1	¼
Potash ration	¼	¼	¼	¼
Plat No	**15**	**24**	**39**	**48**
Nitrogen	1.98	2.37	2.49	2.09
Crude ash	8.32	8.17	9.32	6.69
Silica and insol. matter	.06	.04	.08	.08
Phosphoric acid	.95	.93	1.04	.77
Potassium oxid	1.45	1.50	1.29	1.22
Sodium oxid	2.54	1.98	3.00	1.71
Calcium oxid	.51	.50	.51	.50
Magnesium oxid	.27	.32	.35	.30
Yield, green, pounds	313	315	306	315

CARROT (TOPS), 1901.

	Limed Carbonates.	
Soda ration	1	¼
Potash ration	¼	¼
Plat No	**39**	**48**
Nitrogen	3.08	2.87
Crude ash	14.63	11.89
Silica and insol. matter	.92	.67
Phosphoric acid	.80	.70
Potassium oxid	1.00	1.53
Sodium oxid	4.76	2.17
Calcium oxid	1.54	1.87
Magnesium oxid	.89	.96

WHITE STRASBURG RADISH (ROOTS), 1905.

	Once-Limed Chlorids.			
Soda ration	1	¼	1	¼
Potash ration	¼	¼	¾	¾
Plat No	**3**	**12**	**1**	**11**
Nitrogen	3.50	3.84	3.47	3.65
Phosphoric acid	1.10	1.07	.97	1.03
Potassium oxid	3.17	3.22	6.34	6.13
Sodium oxid	4.08	2.99	3.16	2.99
Calcium oxid	1.42	1.69	1.21	1.31
Magnesium oxid,	.69	.79	.44	.71
Yield, green, pounds	456	398	550	557

WHITE STRASBURG RADISH (ROOTS), 1905.

	Once-limed Chlorids.			
Soda ration	1	½	0	1
Potash ration	1	1	1	0
Plat No	**5**	**8**	**10**	**4**
Nitrogen	3.46	3.52	3.51	4.66
Phosphoric acid	1.02	1.06	1.08	1.24
Potassium oxid	6.75	7.72	6.62	1.95
Sodium oxid	2.73	2.34	1.94	5.43
Calcium oxid	1.00	1.18	1.12	1.55
Magnesium oxid	.76	.58	.83	1.03
Yield, green, pounds	574	542	522	274

WHITE STRASBURG RADISH (ROOTS), 1905.

	Thrice-limed Chlorids.				
Soda ration	1	¼	½	0	¾
Potash ration	¼	¼	1	1	¾
Plat No	**15**	**24**	**20**	**22**	**23**
Nitrogen	4.11	4.03	3.94	3.85	3.76
Phosphoric acid	1.08	.98	1.02	1.02	1.00
Potassium oxid	3.54	2.42	6.67	6.86	5.81
Sodium oxid	4.44	3.50	2.66	2.02	2.85
Calcium oxid	1.59	1.87	1.52	1.28	1.53
Magnesium oxid	.78	.83	.73	.95	.59
Yield, green, pounds	438	324	553	522	498

WHITE STRASBURG RADISH (ROOTS), 1905.

	Once-limed Carbonates.					
Soda ration	1	¼	½	0	1	¾
Potash ration	¼	¼	1	1	¾	¾
Plat No	**27**	**36**	**32**	**34**	**25**	**35**
Nitrogen	4.10	3.76	3.69	3.60	3.77	3.65
Phosphoric acid	1.26	1.15	1.19	1.17	1.16	1.11
Potassium oxid	2.58	2.95	6.19	6.33	5.52	5.03
Sodium oxid	4.11	2.95	2.24	1.71	2.88	2.74
Calcium oxid	1.58	1.66	1.23	1.03	1.20	1.08
Magnesium oxid	.78	.80	.62	.85	.64	.70
Yield, green, pounds	400	372	555	548	556	553

WHITE STRASBURG RADISH (ROOTS), 1905.

	Thrice-limed Carbonates.				
Soda ration	1	¼	1	0	¾
Potash ration	¼	¼	1	1	¾
Plat No	**39**	**48**	**41**	**46**	**47**
Nitrogen	3.87	3.87	3.49	3.77	3.82
Phosphoric acid	1.16	1.03	1.09	1.06	1.12
Potassium oxid	2.60	3.21	5.32	6.05	5.11
Sodium oxid	4.04	2.90	2.64	2.27	2.75
Calcium oxid	1.52	1.67	1.24	1.30	1.32
Magnesium oxid	.76	.80	.79	.85	.65
Yield, green, pounds	398	375	532	508	514

WHITE STRASBURG RADISH, 1905.

	Soda ration, 1; and Potash ration, ¾.			
	Twice-limed Chlorids. Plat No. 13.		Twice-limed Carbonates. Plat No. 37	
	Roots.	*Tops.*	*Roots.*	*Tops.*
Nitrogen	3.88	4.69	3.66	4.93
Phosphoric acid	1.05	1.17	1.01	1.26
Potassium oxid	6.54	3.98	5.43	3.07
Sodium oxid	2.66	2.99	2.75	2.62
Calcium oxid	1.34	4.77	1.37	4.09
Magnesium oxid	.66	.95	.59	.78
Yield, green, pounds	547	520	555	527

STRAP-LEAFED, FLAT TURNIP, 1905.

	Once-limed Chlorids.					
Soda ration	1	½	1	¼	1	0
Potash ration	½	½	¼	¼	¾	1
Plat No.	**2**	**6**	**3**	**12**	**1**	**10**
Nitrogen	2.80	2.41	2.90	3.01	2.72	2.37
Phosphoric acid	1.42	1.29	1.39	1.32	1.28	1.33
Potassium oxid	3.05	2.60	1.99	2.07	3.87	3.93
Sodium oxid	2.42	1.91	3.09	2.14	1.97	1.04
Calcium oxid	.80	.83	.87	.99	.95	.80
Magnesium oxid	.35	.37	.31	.40	.34	.47
Yield, green, pounds	402	390	373	240	379	417

STRAP-LEAFED, FLAT TURNIP, 1905.

	Thrice-limed Chlorids.				
Soda ration	1		½	1	¼
Potash ration	½		½	¼	¼
Plat No.	**14**		**18**	**15**	**24**
	Tops.	*Roots.*	*Roots.*	*Roots.*	*Roots.*
Nitrogen	3.28	2.46	2.64	3.08	3.13
Phosphoric acid	1.31	1.26	1.26	1.35	1.29
Potassium oxid	2.28	2.72	2.48	1.96	1.79
Sodium oxid	2.44	2.49	2.30	3.59	2.94
Calcium oxid	5.29	.93	1.00	.99	1.17
Magnesium oxid	1.04	.36	.35	.37	.38
Yield, green, pounds	647	377	340	294	192

STRAP–LEAFED, FLAT TURNIP, 1905.

	Thrice-limed Chlorids.					
Soda ration	1	½	0		1	¾
Potash ration	1	1	1		¾	¾
Plat No	**17**	**20**	**22**		**13**	**23**
	Roots.	*Roots.*	*Tops.*	*Roots.*	*Roots.*	*Roots.*
Nitrogen	2.32	2.22	3.25	2.55	2.24	2.51
Phosphoric acid	1.31	1.28	1.33	1.28	1.23	1.33
Potassium oxid	3.82	3.94	3.28	3.69	3.15	3.33
Sodium oxid	1.71	1.38	1.45	1.23	1.70	2.09
Calcium oxid	.91	1.03	4.98	.98	.90	1.02
Magnesium oxid	.36	.41	1.58	.50	.38	.33
Yield, green, pounds	382	392	640	369	371	376

STRAP–LEAFED, FLAT TURNIP (ROOTS), 1905.

	Once-limed Carbonates.			
Soda ration	1	½	1	¼
Potash ration	½	½	¼	¼
Plat No	**26**	**30**	**27**	**36**
Nitrogen	2.54	2.77	3.33	3.07
Phosphoric acid	1.42	1.41	1.47	1.45
Potassium oxid	2.48	2.29	1.68	1.92
Sodium oxid	2.39	2.12	3.46	2.45
Calcium oxid	.87	1.00	.90	1.04
Magnesium oxid	.36	.36	.38	.40
Yield, green, pounds	385	311	269	227

SRAP–LEAFED, FLAT TURNIP (ROOTS), 1905.

	Once-limed Carbonates.			
Soda ration	1	½	0	1
Potash ration	1	1	1	¾
Plat No	**29**	**32**	**34**	**35**
Nitrogen	2.40	2.22	2.53	2.61
Phosphoric acid	1.40	1.41	1.40	1.46
Potassium oxid	3.45	3.53	3.53	2.80
Sodium oxid	1.66	1.47	1.26	1.99
Calcium oxid	.90	.81	.78	.84
Magnesium oxid	.35	.34	.46	.38
Yield, green, pounds	358	420	414	389

STRAP–LEAFED, FLAT TURNIP (ROOTS), 1905.

	Thrice-limed Carbonates.			
Soda ration	1	¼	½	¾
Potash ration	¼	¼	½	¾
Plat No	**39**	**48**	**42**	**47**
Nitrogen	2.67	3.28	2.70	2.60
Phosphoric acid	1.39	1.30	1.38	1.41
Potassium oxid	2.94	2.03	2.62	3.25
Sodium oxid	2.13	2.47	2.04	1.72
Calcium oxid	.89	1.15	.90	.88
Magnesium oxid	.39	.41	.40	.37
Yield, green, pounds	372	246	343	404

STRAP–LEAFED, FLAT TURNIP (ROOTS), 1905.

	Thrice-limed Carbonates.			
Soda ration	1	½	0	1
Potash ration	1	1	1	¾
Plat No	**41**	**44**	**46**	**37**
Nitrogen	2.45	2.59	2.52	2.42
Phosphoric acid	1.42	1.43	1.31	1.38
Potassium oxid	3.50	3.88	3.49	3.22
Sodium oxid	1.75	1.38	1.27	1.90
Calcium oxid	.74	.89	.88	.92
Magnesium oxid	.46	.41	.42	.38
Yield, green, pounds	394	399	384	392

REPORT OF METEOROLOGIST.

NATHANIEL HELME.

Summary, July 1, 1905, to June 30, 1906.

Temperature.

Maximum	92°	July 19, 1905.
Minimum	—3°	January 10, 1906.
Highest daily mean	80°	July 18, and 19, 1905.
Lowest daily mean	9°	February 3, 1906.
Highest monthly mean	70.3°	July, 1905.
Lowest monthly mean	28.6°	February, 1906.
Mean temperature of the year	48.4°	

Precipitation. (*Rain and melted Snow.*)

Total for the year	53.57	inches.
Largest monthly	6.34	inches, March, 1906.
Least monthly	1.75	inches, October, 1905.
Greatest in any 24 consecutive hours	2.21	inches, Sept. 4, 1905.
Snowfall (unmelted)	27	inches, December, 3 inches; January, 9 inches; February, 4 inches; March, 11 inches.

Prevailing Winds.

Southwest; July, August, 1905; May, June, 1906. West; September, October, November, December, 1905; January, February, March, 1906. Northwest; April, 1906.

Weather.

Number of clear days in the year	175
Partly cloudy days	99
Cloudy days	91
Days with .01 inch or more of precipitation	97

Summary by months, 1905–1906.

MONTHS.	Maximum Temperature.	Minimum Temperature.	Mean Temperature.	Precipitation (rain and melted snow), inches.	Snowfall (unmelted).	Clear Days.	Partly Cloudy Days.	Cloudy Days.	Days with .01 inch or more of Precipitation.	Prevailing Winds.
1905.										
July	92°	50°	70.3°	3.71	......	15	7	9	8	S. W.
August	87°	45°	66.3°	4.66	......	15	6	10	11	S. W.
September	79°	33°	60.4°	5.86	......	16	3	11	11	W.
October	79°	27°	51.8°	1.75	......	20	6	5	5	W.
November	63°	12°	39.6°	4.23	......	18	9	3	6	W.
December	58°	9°	33.2°	5.71	3	15	7	9	6	W.
1906.										
January	62°	—3°	33°	5.16	9	13	11	7	12	W.
February	56°	—2°	28.6°	4.71	4	12	9	7	6	W.
March	53°	5°	31.2°	6.34	11	13	9	9	11	W.
April	72°	20°	45.4°	3.72	......	12	12	6	7	N. W.
May	86°	32°	56.4°	4.56	......	16	9	6	8	S. W.
June	87°	42°	64.4°	3.16	......	10	11	9	6	S. W.
Total	......	......	......	53.57	27	175	99	91	97	......
Mean	72.8°	22.5°	48.4°	......	......	......	......	......	......	......

The principal characteristics of the weather for each month were as follows:

The mean temperature of July and the precipitation were both slightly above the average, and the weather was favorable for gathering the hay crop.

The mean temperature of August was slightly below and the rainfall above, the average. The weather of the month was about the normal, the precipitation being well distributed.

The rainfall for September was above, and the temperature below, the average. There was killing frost on low land on the morning of the 27th.

The precipitation for October was below the average, and the least for the month since 1897. Fine weather for harvesting and out-door labor prevailed during the month. There were killing frosts on the 23rd, 26th, 27th and 30th. The mean temperature was slightly below the average.

The weather for November was unusually pleasant there being but three cloudy days in the month. The temperature and precipitation were each below the average.

The mean temperature of December was ten degrees higher than that of the same month in 1904. The ground was bare of snow for the greater part of the time and at the end of the month there was practically no frost in the ground.

It was the warmest January since 1890 and the maximum temperature was the highest for the month on our record. There was no frost in the ground at the end of the month.

With the exception of three days, the ground was bare of snow during the whole month of February. Robins and blue birds were seen, daffodils were in bud and willows were already in bloom by the latter part of the month.

The mean temperature of March was less than that of either December or January. It was below the average for the month for seventeen years, and but twice during that period has it been lower, viz. in 1896 (30.6°) and 1900 (29.4°). The precipitation was above the average while the snowfall was greater than in any one of the winter months. The minimum temperature of 6° on the 24th, was something unusual for so late a date in the month.

The mean temperature of April was slightly above, and the precipitation below, the average for the month. There were killing frost on the 24th and 26th.

The precipitation and temperature of May were each above the average. There was killing frost on the 11th and on low land on the 22nd.

The record for June shows a mean temperature above, and precipitation below, the average. The month ended with one of the severest thunder storms that has been experienced here for several years, considerable damage being done by lightning.

The following tables show the maximum, minimum, and mean temperature, character of day, precipitation and prevailing wind for each day in the year; and also a general summary from January 1, 1890, to June 30, 1906, inclusive.

WEATHER SUMMARY FOR JULY, 1905.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	MAX.	MIN.	MEAN.			
1	77	54	65.5	....	S. W.	Cloudy.
2	68	61	64.5	.11	S.	Cloudy.
3	81	61	71	....	Variable.	Clear.
4	88	59	73.5	....	W.	Clear.
5	70	57	63.5	....	S.	Cloudy.
6	75	59	67	....	S.	Fair.
7	80	61	70.5	....	S. W.	Cloudy.
8	83	63	73	....	S. E.	Fair.
9	85	64	74.5	....	S. W.	Clear.
10	89	66	77.5	....	W.	Clear.
11	87	67	77	....	S. W.	Clear.
12	85	68	76.5	1.38	S. W.	Fair.
13	84	70	77	....	S. W.	Fair.
14	83	67	75	.17	S. W.	Fair.
15	82	61	71.5	....	W.	Clear.
16	78	54	66	....	S. W.	Clear.
17	88	63	75.5	.48	S. W.	Fair.
18	91	69	80	....	S. W	Clear.
19	92	68	80	Trace.	S. W.	Clear.
20	85	63	74	....	W.	Clear.
21	82	59	70.5	....	W.	Clear
22	79	56	67.5	....	S. W.	Fair.
23	65	58	61.5	.46	N. E.	Cloudy.
24	70	54	62	.36	S.	Cloudy.
25	78	56	67	....	W.	Clear.
26	77	51	64	....	W.	Clear.
27	80	50	65	....	W.	Clear.
28	82	56	69	....	S.	Clear.
29	74	63	68.5	.27	E.	Cloudy.
30	76	63	69.5	.48	Variable.	Cloudy.
31	67	58	62.5	....	N. W.	Cloudy.
Sum........	2,481	1,879	2,180	3.71	....	....
Mean.......	80	60.6	70.3	....	....	....

Maximum temperature........92°. **Mean temperature........70.3°.**
Minimum temperature........50°. **Prevailing wind..........S. W.**

WEATHER SUMMARY FOR AUGUST, 1905.

	TEMPERATURE			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	MAX.	MIN.	MEAN.			
1	64°	55°	59.5°	.13	N.	Cloudy.
2	79	52	65.5	....	W.	Clear.
3	80	55	67.5	....	N. W.	Clear.
4	79	56	67.5	....	W.	Clear.
5	80	62	71	....	S.	Clear.
6	81	61	71	....	S. W.	Clear.
7	86	66	76	....	S. W.	Clear.
8	82	61	71.5	....	S. W.	Cloudy.
9	78	67	72.5	.58	S. W.	Rainy.
10	79	66	72.5	....	S. W.	Cloudy.
11	83	70	76.5	....	S. W.	Fair.
12	83	69	76	.08	S. W.	Cloudy.
13	82	65	73.5	.40	Variable.	Cloudy.
14	73	60	66.5	....	N. E.	Fair.
15	62	54	58	1.42	N. E.	Rainy.
16	58	53	55.5	.36	N. E.	Cloudy.
17	72	46	59	....	Variable.	Clear.
18	71	46	58.5	....	N. E.	Clear.
19	69	49	59	....	N. E.	Clear.
20	73	49	61	....	S.	Fair.
21	80	58	69	....	S. W.	Clear.
22	82	60	71	....	S. W.	Clear.
23	87	63	75	....	N. W.	Clear.
24	85	57	71	.15	S. W.	Fair.
25	72	58	65	.33	N. E.	Cloudy.
26	74	54	64	....	N. E.	Fair.
27	66	46	56	.16	N. E.	Clear.
28	72	45	58.5	....	N. W.	Clear.
29	75	54	64.5	.18	N. W.	Fair.
30	73	54	63.5	.87	S. W.	Cloudy.
31	66	53	59.5	....	N.	Clear.
Sum........	2,346	1,764	2,055	4.66	....	....
Mean.......	75.7	56.9	66.3	....	....	....

Maximum temperature........87°.
Minimum temperature........45°.
Mean temperature..........66.3°
Prevailing wind............S. W.

WEATHER SUMMARY FOR SEPTEMBER, 1905.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	MAX.	MIN.	MEAN.			
1	68°	49°	58.5°	Trace.	S.	Fair.
2	72	54	63	.02	S.	Cloudy.
3	65	60	62.5	2.17	S. E.	Rainy.
4	72	65	68.5	2.21	S.	Rainy.
5	77	59	68	....	S. W.	Fair.
6	73	53	63	.03	S. W.	Clear.
7	74	53	63.5	....	W.	Clear.
8	72	51	61.5	....	Variable.	Clear.
9	78	52	65	....	W.	Clear.
10	79	53	66	....	S. W.	Clear.
11	69	55	62	.20	S.	Cloudy.
12	66	57	61.5	.82	S. E.	Rainy.
13	70	55	62.5	....	N. W.	Cloudy.
14	63	41	52	....	N. W.	Clear.
15	64	38	51	....	Variable.	Fair.
16	65	48	56.5	....	S.	Cloudy.
17	70	58	64	.03	S. E.	Cloudy.
18	72	57	64.5	.10	E.	Cloudy.
19	68	60	64	.15	N. E.	Cloudy.
20	66	59	62.5	.13	S. E.	Rain and fog.
21	72	54	63	....	N. W.	Clear.
22	79	50	64.5	....	S. W.	Clear.
23	71	50	60.5	....	W.	Clear.
24	65	43	54	....	W.	Clear.
25	62	42	52	....	W.	Clear.
26	58	34	46	....	W.	Clear.
27	63	33	48	....	W.	Clear.
28	72	44	58	....	S. W.	Clear.
29	70	49	59.5	....	S. W.	Clear.
30	79	53	66	....	W.	Clear.
Sum........	2,094	1,529	1,811.5	5.86	....	....
Mean.......	69.8	51	60.4	....	....	....

Maximum temperature........79°.
Minimum temperature........33°.

Mean temperature.........60.4°.
Prevailing wind............W.

WEATHER SUMMARY FOR OCTOBER, 1905.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	MAX.	MIN.	MEAN.			
1	69°	50°	59.5°	....	Variable.	Clear.
2	64	50	57	....	S. E.	Cloudy.
3	75	55	65	.09	W.	Fair.
4	78	46	62	....	W.	Clear.
5	79	55	67	....	W.	Clear.
6	62	42	52	....	N.	Clear.
7	62	36	49	....	Variable.	Clear.
8	67	37	52	....	W.	Clear.
9	77	50	63.5	....	Variable.	Clear.
10	61	41	51	....	S.	Clear.
11	56	47	51.5	.39	E.	Cloudy.
12	62	40	51	....	W.	Clear.
13	60	32	56	....	W.	Clear.
14	68	42	55	....	W.	Clear.
15	77	47	62	....	S. W.	Clear.
16	73	54	63.5	....	S. W.	Fair.
17	64	39	51.5	....	S. W.	Clear.
18	66	42	54	....	S. E.	Fair.
19	73	60	66.5	.04	S. E.	Cloudy.
20	61	54	57.5	1.15	Variable.	Rainy.
21	54	34	44	....	N. W.	Clear.
22	53	27	40	....	W.	Fair.
23	53	32	42.5	....	W.	Clear.
24	60	33	46.5	.08	S. W.	Fair.
25	54	41	47.5	....	W.	Cloudy.
26	47	29	38	....	N.	Clear.
27	52	27	39.5	....	N.	Clear.
28	59	33	46	....	N. E.	Clear.
29	50	33	41.5	....	N. E.	Clear.
30	51	29	40	....	N. E.	Clear.
31	54	32	43	....	S. E.	Fair.
Sum........	1,941	1,269	1,605	1.75	....	....
Mean.......	62.6	40.9	51.8	....	....	....

Maximum temperature........79°.
Minimum temperature........27°.
Mean temperature........51.8°.
Prevailing wind......... west.

WEATHER SUMMARY FOR NOVEMBER, 1905.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	MAX.	MIN.	MEAN.			
1	63°	35°	49°	....	S. W.	Fair.
2	46	23	34.5	....	W.	Clear.
3	52	27	39.5	....	S. E.	Fair.
4	52	34	43	1.34	N. W.	Clear.
5	54	31	42.5	....	W.	Fair.
6	53	39	46	.26	Variable.	Fair.
7	52	32	42	....	N. E.	Fair.
8	48	32	40	....	W.	Fair.
9	48	26	37	....	W.	Clear.
10	45	24	34.5	....	W.	Clear.
11	48	23	35.5	....	S. W.	Clear.
12	55	35	45	....	S. W.	Clear.
13	57	38	47.5	Trace.	S. W.	Fair.
14	42	12	27	....	N. W.	Clear.
15	48	15	31.5	.30	S.	Fair.
16	48	38	43	....	W.	Cloudy.
17	43	31	37	....	W.	Fair.
18	48	30	39	....	W.	Clear.
19	48	24	36	....	N. W.	Clear.
20	38	19	28.5	....	N.	Clear.
21	49	23	60.5	....	W.	Clear.
22	53	23	38	....	W.	Clear.
23	57	29	43	....	W.	Clear.
24	58	37	47.5	....	S. W.	Clear.
25	63	39	51	.05	W.	Clear.
26	52	32	42	....	N. E.	Clear.
27	47	28	37.5	....	W.	Clear.
28	48	22	35	.03	S. E.	Cloudy.
29	55	45	50	2.25	S. E.	Rainy.
30	58	14	36	....	N. W.	Clear.
Sum.........	1,518	860	1,189	4.23	....	....
Mean.......	50.6	28.7	39.6	....	....	....

Maximum temperature.........63°.
Minimum temperature.........12°.

Mean temperature.......39.6°.
Prevailing wind..........west.

WEATHER SUMMARY FOR DECEMBER, 1905.

	Temperature.			Precipitation.	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	33°	9°	21°	....	N. W.	Clear.
2	49	18	33.5	Trace.	S.	Cloudy.
3	58	40	49	1.92	S.	Rainy.
4	40	23	31.5	....	W.	Clear.
5	33	15	24	....	W.	Clear.
6	41	18	29.5	....	W.	Fair.
7	45	24	34.5	....	W.	Clear.
8	51	28	39.5	....	W.	Clear.
9	38	26	32	.05	N. E.	Cloudy.
10	36	19	27.5	1.00	N. W.	Fair.
11	35	10	22.5	....	W.	Cloudy.
12	35	22	28.5	....	N. E.	Fair.
13	45	21	33	....	W.	Fair.
14	35	19	27	....	W.	Clear.
15	22	9	15.5	....	N. E.	Cloudy.
16	33	17	25	....	N. E.	Fair.
17	33	25	29	.01	N.	Cloudy.
18	52	22	37	....	W.	Clear.
19	43	26	34.5	....	Variable.	Fair.
20	50	30	40	....	N. W.	Clear.
21	52	30	41	1.70	S. W.	Cloudy.
22	52	38	45	....	W.	Clear.
23	47	32	39.5	.15	S. W.	Cloudy.
24	40	24	32	....	W.	Clear.
25	38	18	28	....	W.	Clear.
26	40	18	29	....	W.	Clear.
27	47	28	37.5	....	W.	Clear.
28	57	28	42.5	....	W.	Clear.
29	54	35	44.5	.88	S.	Rainy.
30	49	33	41	....	W.	Clear.
31	43	25	34	....	W.	Fair.
Sum........	1,326	730	1,028	5.71	....	....
Mean.......	42.8	23.6	33.2	....	....	....

Maximum temperature.........58°. Mean temperature........33.2°.
Minimum temperature......... 9°. Prevailing wind...........west.

WEATHER SUMMARY FOR JANUARY, 1906.

	Temperature.			Precipitation.	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	39°	18°	28.5°	....	N. W.	Clear.
2	35	19	27	....	W.	Fair.
3	32	19	25.5	.09	N. E.	Fair.
4	53	31	42	1.85	S.	Cloudy.
5	45	30	37.5	....	W.	Fair.
6	40	27	33.5	....	W.	Clear.
7	35	19	27	.05	W.	Clear.
8	27	17	22	.10	E.	Cloudy.
9	25	9	17	.25	W.	Clear.
10	26	-3	11.5	....	W.	Clear.
11	38	16	27	....	S.	Fair.
12	54	30	42	.03	Variable.	Cloudy.
13	37	27	32	....	N. E.	Cloudy.
14	36	24	30	.90	N.	Cloudy.
15	37	18	27.5	....	Variable.	Fair.
16	48	33	40.5	.96	S.	Fair.
17	38	26	32	....	W.	Clear.
18	42	24	33	.28	S. W.	Fair.
19	41	25	33	.03	W.	Clear.
20	42	24	33	....	S. E.	Cloudy.
21	58	41	49.5	....	S. W.	Fair.
22	60	40	50	....	S. W.	Clear.
23	62	47	54.5	....	S.	Cloudy.
24	53	28	40.5	.36	N. W.	Fair.
25	29	14	21.5	....	N.	Fair.
26	36	16	26	....	N. E.	Clear.
27	48	25	36.5	....	E.	Clear.
28	47	33	40	.26	N.	Fair.
29	38	17	27.5	....	N.	Clear.
30	46	20	33	....	S. W.	Clear.
31	52	33	42.5	....	S.	Clear.
Sum........	1,299	747	1,023	5.16	....	....
Mean.......	41.9	24.1	33	....	....	....

Maximum temperature.........62°.	Mean temperature........33°.
Minimum temperature.........-3°.	Prevailing wind...........west.

WEATHER SUMMARY FOR FEBRUARY, 1906.

	Temperature.			Precipitation.	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	45°	27°	36°	....	W.	Fair.
2	35	3	19	....	N. W.	Clear.
3	20	—2	9	....	W.	Clear.
4	41	10	25.5	....	S. W.	Cloudy.
5	48	19	33.5	....	S. W.	Fair.
6	22	4	13	....	N.	Fair.
7	22	10	16	....	N.	Fair.
8	31	6	18.5	....	E.	Fair.
9	37	24	30.5	1.78	N. E.	Rain & Snow
10	35	20	27.5	....	W.	Clear.
11	29	10	19.5	....	N. W.	Clear.
12	39	22	30.5	....	N. E.	Cloudy.
13	39	33	36	.43	N. E.	Rain & fog.
14	48	32	40	.02	Variable.	Cloudy.
15	35	14	24.5	....	N. W.	Fair.
16	35	8	21.5	....	N. W.	Clear.
17	38	13	25.5	....	E.	Clear.
18	37	21	29	.05	S. W.	Fair.
19	44	25	34.5	....	W.	Fair.
20	49	28	38.5	....	S. W.	Clear.
21	56	35	45.5	2.07	S.	Rainy.
22	51	29	40	....	N. W.	Clear.
23	43	25	34	....	Variable.	Clear.
24	52	25	38.5	....	S. W.	Clear.
25	36	28	32	.36	S. E.	Cloudy.
26	47	27	37	....	N. W.	Clear.
27	39	18	28.5	....	N.	Fair.
28	25	9	17	....	N. W.	Clear.
Sum........	1,078	523	800.5	4.71	....	....
Mean.......	38.5	18.7	28.6	....	....	....

Maximum temperature.........56°.
Minimum temperature........—2°.
Mean temperature.........28.6°.
Prevailing wind...........west.

WEATHER SUMMARY FOR MARCH, 1906.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	MAX.	MIN.	MEAN.			
1	31°	5°	18°	....	W.	Clear.
2	41	14	27.5	....	W.	Clear.
3	47	26	36.5	.91	N. E.	Rainy.
4	52	35	43.5	1.25	W.	Cloudy.
5	46	26	36	....	N. W.	Clear.
6	39	17	28	....	S. E.	Clear.
7	46	22	34	....	S. W.	Fair.
8	48	33	40.5	.10	S. W.	Fair.
9	42	29	35.5	.37	N. W.	Rainy.
10	50	29	39.5	....	S. W.	Clear.
11	48	25	36.5	....	W.	Fair.
12	44	26	35	.18	N. W.	Fair.
13	32	10	21	....	Variable.	Fair.
14	31	16	23.5	....	N. E.	Fair.
15	30	12	21	1.00	N. E.	Rain & Snow.
16	41	12	26.5	....	N. W.	Clear.
17	33	16	24.5	....	N. W.	Clear.
18	33	12	22.5	....	N. W.	Clear.
19	37	16	26.5	1.10	E.	Rain & Snow
20	42	24	33	....	W.	Fair.
21	38	15	26.5	....	S. W.	Clear.
22	44	21	34.5	....	W.	Clear.
23	30	10	20	....	N. W.	Clear.
24	33	6	19.5	....	N.	Clear.
25	38	15	26.5	....	E.	Clear.
26	40	21	30.5	.11	E.	Rainy.
27	50	38	44	.31	S.	Rainy.
28	48	35	41.5	....	W.	Fair.
29	53	29	41	....	W.	Fair.
30	42	37	39.5	.92	N. E.	Rainy.
31	45	32	38.5	.09	N. W.	Cloudy.
Sum........	1,274	664	969	6.34	....	....
Mean.......	41.1	21.4	31.2	....	....	....

Maximum temperature.........53°.
Minimum temperature......... 5°.
Mean temperature........31.2°.
Prevailing wind...........west.

WEATHER SUMMARY FOR APRIL, 1906.

	Temperature.			Precipitation.	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	48°	20°	34°	....	N. W.	Clear.
2	43	22	32.5	....	N. W.	Clear.
3	50	23	36.5	....	S. W.	Clear.
4	62	27	44.5	....	S. W.	Fair.
5	62	38	50	....	W.	Fair.
6	48	37	42.5	.30	W.	Fair.
7	50	26	38	....	W.	Clear.
8	52	31	41.5	....	N.	Clear.
9	43	29	36	.45	N. E.	Rainy.
10	56	35	45.5	2.02	Variable.	Rainy.
11	57	35	46	....	N. W.	Fair.
12	54	39	46.5	....	N. W.	Fair.
13	55	32	43.5	....	W.	Clear.
14	52	34	43	....	S. E.	Cloudy.
15	53	46	49.5	.29	S. E.	Rainy.
16	59	42	50.5	....	N. W.	Fair.
17	62	35	48.5	....	W.	Clear.
18	68	39	53.5	....	S. W.	Clear.
19	62	35	48.5	....	S. E.	Fair.
20	58	39	48.5	....	S. E.	Fair.
21	72	41	56.5	....	S. W.	Fair.
22	62	43	52.5	.02	S. W.	Fair.
23	44	37	40.5	.26	N. E.	Rainy.
24	55	32	43.5	....	N. W.	Fair.
25	55	35	45	....	N. W.	Fair.
26	61	30	45.5	....	W.	Clear.
27	60	40	50	....	W.	Clear.
28	62	40	51	....	N. W.	Clear.
29	63	38	50.5	....	W.	Clear.
30	57	40	48.5	.38	S.	Rainy.
Sum........	1,685	1,040	1,362.5	3.72	....	....
Mean.......	56.2	34.7	45.4	....	....	....

Maximum temperature.........72°. Mean temperature........45.4°.
Minimum temperature.........20°. Prevailing wind...........northwest.

WEATHER SUMMARY FOR MAY, 1906.

	TEMPERATURE.			PRECIPITATION.	PREVAILING WIND.	CHARACTER OF DAY.
	MAX.	MIN.	MEAN.			
1	70°	42°	56°	....	W.	Clear.
2	58	41	49.5	.52	S.	Rainy.
3	69	48	58.5	....	W.	Fair.
4	58	38	48	....	S. W.	Clear.
5	73	48	60.5	....	S. W.	Clear.
6	67	51	59	Trace.	S.	Cloudy.
7	58	46	52	.88	N. W.	Cloudy.
8	61	42	51.5	....	N. W.	Clear.
9	60	39	49.5	.02	S.	Fair.
10	50	38	44	....	N. W.	Fair.
11	57	32	44.5	....	W.	Clear.
12	62	37	49.5	....	S. W.	Clear.
13	80	53	66.5	....	S. W.	Fair.
14	67	42	54.5	.34	Variable.	Fair.
15	60	38	49	....	Variable.	Clear.
16	79	38	58.5	....	S. W.	Clear.
17	76	51	63.5	....	S. W.	Fair.
18	86	58	72	....	S. W.	Clear.
19	86	58	72	....	W.	Clear.
20	69	45	57	....	W.	Clear.
21	60	38	49	....	S. W.	Clear.
22	65	37	51	....	S. W.	Clear.
23	72	42	57	....	S. W.	Clear.
24	79	51	65	.04	S. W.	Fair.
25	82	56	69	....	S. W.	Clear.
26	75	50	62.5	....	S. W.	Fair.
27	63	58	60.5	.13	S.	Cloudy.
28	60	44	52	2.15	N. E.	Rainy.
29	62	42	52	.48	N. W.	Fair.
30	68	41	54.5	....	N. W.	Clear.
31	70	50	60	....	S. W.	Cloudy.
Sum........	2,102	1,394	1,748	4.56	....	....
Mean.......	67.8	45	56.4	....	....	....

Maximum temperature.........86°.	Mean temperature........56.4°.
Minimum temperature.........32°.	Prevailing wind...........southwest.

WEATHER SUMMARY FOR JUNE, 1906.

	Temperature.			Precipitation.	Prevailing Wind.	Character of Day.
	Max.	Min.	Mean.			
1	78°	50°	64°	....	S. W.	Cloudy.
2	75	56	65.5	....	S. W.	Cloudy.
3	77	54	65.5	....	W.	Clear.
4	73	51	62	....	S. W.	Clear.
5	77	52	64.5	....	S. W.	Fair.
6	77	57	67	.48	S. W.	Cloudy.
7	68	51	59.5	....	N. E.	Fair.
8	60	47	53.5	....	N. E.	Cloudy.
9	77	55	66	.21	S. W.	Cloudy.
10	82	59	70.5	....	W.	Clear.
11	72	52	62	....	N. W.	Fair.
12	65	42	53.5	....	Variable.	Clear.
13	72	47	59.5	....	Variable.	Clear.
14	78	50	64	....	W.	Clear.
15	83	50	66.5	....	S. E.	Clear.
16	60	52	56	1.37	E.	Rainy.
17	75	58	66.5	.35	E.	Cloudy.
18	60	56	58	.15	N. E.	Cloudy.
19	68	53	60.5	....	N. E.	Fair.
20	76	49	62.5	....	S. E.	Clear.
21	73	51	62	....	E.	Fair.
22	74	61	67.5	....	S. W.	Clear.
23	78	55	66.5	....	S. W.	Fair.
24	71	54	62.5	....	E.	Fair.
25	77	55	66	....	W.	Fair.
26	77	55	66	....	W.	Fair.
27	83	59	71	....	S. W.	Clear.
28	87	63	75	....	Variable.	Fair.
29	85	63	74	....	W.	Fair.
30	87	59	73	.60	W.	Fair.
Sum........	2,245	1,616	1,[illegible].5 ~~1,390.5~~	3.16	....	....
Mean........	74.8	53.9	64.4	....	....	....

Maximum temperature..........87°.
Minimum temperature..........42°.
Mean temperature.........64.4°.
Prevailing wind...........southwest

SUMMARY, JANUARY 1, 1890, TO JUNE 30, 1906, INCLUSIVE.

	Maximum Temperature.	Minimum Temperature.	Mean Temperature.	Number of Clear Days.	Partly Cloudy Days.	Cloudy Days.	Days with .01 inch or more of Precipitation.	Total Precipitation, inches.
1890	91°	3°	48.3°	99	143	123	120	59.25
1891	94°	5°	49.4°	116	154	95	83	49.88
1892	92°	—1°	47.8°	147	116	103	89	42.56
1893	92°	—6°	46.5°	126	130	109	131	57.33
1894	93°	—9°	48.6°	110	130	125	114	48.19
1895	93°	—7°	48.2°	128	114	123	108	49.28
1896	93°	—11°	47.7°	131	112	123	109	49.87
1897	90°	—1°	48.3°	129	126	110	128	54.25
1898	95°	—4°	48.8°	110	114	141	131	72.21
1899, Jan. 1, to June 30	95°	—10°	42.1°	77	44	60	59	26.79
July 1, 1899, to June 30, 1900	90°	—5°	48.3°	141	113	111	102	51.67
July 1, 1900, to June 30, 1901	97°	—9°	48.4°	134	97	134	114	48.47
July 1, 1901, to June 30, 1902	93°	—1°	48°	138	116	111	109	53.14
July 1, 1902, to June 30, 1903	90°	—12°	48.3°	138	96	131	103	59.27
July 1, 1903, to June 30, 1904	93°	—16°	45.7°	156	107	103	118	50.06
July 1, 1904, to June 30, 1905	87°	—4°	45.3°	151	122	92	99	41.64
July 1, 1905, to June 30, 1906	92°	—3°	48.4°	175	99	91	97	53.57

Average temperature, 16½ years, 47.5°. **Average precipitation, 16½ years, 52.57 inches.**

REPORT OF THE TREASURER.

THE RHODE ISLAND AGRICULTURAL EXPERIMENT STATION, *in account with the* UNITED STATES APPROPRIATION, 1905–1906.

1906.	DR.		
	To receipts from the treasurer of the United States as per appropriation for fiscal year ended June 30, 1906, as per act of Congress approved March 2, 1887		$15,000 00

1906.	CR.		
	By Salaries	$8,738 82	
	Labor	2,132 92	
	Publications	53 01	
	Postage and stationery	206 34	
	Freight and express	177 06	
	Heat, light, water, and power	478 51	
	Chemical supplies	40 58	
	Seeds, plants, and sundry supplies	286 71	
	Fertilizers	276 20	
	Feeding-stuffs	538 69	
	Library	439 75	
	Tools, implements, and machinery	485 13	
	Furniture and fixtures	131 49	
	Scientific apparatus	3 55	
	Live stock	212 70	
	Traveling expenses	211 35	
	Contingent expenses	15 00	
	Buildings and repairs	572 19	
			$15,000 00

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the Rhode Island Agricultural Experiment Station for the fiscal year ended June 30, 1906; that we have found the same well kept and classified as above, and that the receipts for the year from the treasurer of the United States are shown to have been $15,000, and the corresponding disbursements $15,000, for all of which proper vouchers are on file, and have been examined by us and found correct, thus leaving no balance.

And we further certify that the expenditures have been solely for the purposes set forth in the act of Congress approved March 2, 1887.

CHARLES DEAN KIMBALL,
R. S. BURLINGAME,
Auditors.

THE RHODE ISLAND AGRICULTURAL EXPERIMENT STATION, *in account with the* UNITED STATES APPROPRIATION, 1905–1906.

1906.	DR.		
	To receipts from the treasurer of the United States as per appropriation for fiscal year ended June 30, 1906, as per act of Congress approved March 16, 1906		$5,000 00
1906.	CR.		
	By Salaries	$496 30	
	Chemical supplies	143 26	
	Seeds, plants, and sundry supplies	39 97	
	Fertilizers	3 00	
	Library	222 21	
	Tools, implements, and machinery	531 20	
	Scientific apparatus	835 95	
	Traveling expenses	192 31	
	Balance	2,535 80	
			$5,000 00

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the Rhode Island Agricultural Experiment Station for the fiscal year ended June 30, 1906; that we have found the same well kept and classified as above, and that the receipts for the year from the treasurer of the United States are shown to have been $5,000.00, and the corresponding disbursements $2,464.20; for all of which proper vouchers are on file and have been by us examined and found correct, thus leaving $2,535.80 as balance on hand.

And we further certify that the expenditures have been solely for the purposes set forth in the act of Congress approved March 16, 1906.

CHARLES DEAN KIMBALL,
R. S. BURLINGAME,
Auditors.

C. H. COGGESHALL, *Treasurer, in account with the* RHODE ISLAND AGRICULTURAL EXPERIMENT STATION, *for the year ended June* 30, 1906.

1906.	DR.	
	To Balance from last year	$3,216 91
	Station receipts	479 45
	Interest	106 88
		$3,803 24

1906.	CR.	
	By Publications	$2 25
	Postage and stationery	24 54
	Seeds, plants, and sundry supplies	13 35
	Traveling expenses	4 69
	Contingent expenses	23 30
	Buildings and repairs	13 48
	Balance	3,721 63
		$3,803 24

This certifies that we, the undersigned, auditing committee of the Board of Managers of the Rhode Island College of Agriculture and Mechanic Arts, have examined the account of C. H. Coggeshall, treasurer of the Rhode Island Agricultural Experiment Station, and find the same correct.

The total receipts were $3,803.24, and the total expenditures were $81.61, thus leaving a balance to new account of $3,721 63.

CHARLES DEAN KIMBALL,
R. S. BURLINGAME,
Auditors.

Directions for Binding the Bulletins and Reports of the Rhode Island Experiment Station.

Vol.	1–3,*	Bulletins	1–9,	Reports,	1–3,	1888–1890.
"	4,	"	10–14,	Report,	4,	1891.
"	5,	"	15–20,	"	5,	1892.
"	6,	"	21–26,	"	6,	1893.
"	7,	"	27–30,	"	7,	1894.
"	8,	"	31–35,	"	8,	1895.
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"	11,	"	47–51,	"	11,	1898.
"	12,	"	52–55	"	12,	1899.
"	13,	"	56–69,	"	13,	1899–1900.
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* Vols. 1–3 in one cover. Beginning with volume 4, a title page and index for each volume is to be found at the end of the annual report for each year. The year covered by a volume formerly was the calendar year, but now it extends from July 1 to June 30. Each volume, beginning with volume 4, is paged separately. The Bulletins of a given year precede the Report, and the latter is paged in continuation of the last Bulletin belonging in the volume.

EXCHANGES.

Aboriculture, Connersville, Ind.
Agricultural Advertising, Pittsburg, Pa.
Agricultural Epitomist, Spencer, Ind.
Agricultural Gazette of New South Wales, Australia.
Agricultural Ledger, Calcutta, India.
American Cultivator, Boston, Mass.
American Fancier, Johnstown, N. Y.
American Farm World, Augusta, Maine.
American Fertilizer, Philadelphia, Pa.
American Hay, Flour and Feed Journal, New York.
American Horse Breeder, Boston, New York and Chicago.
American Fruit and Nut Journal, Petersburg, Va.
American Philosophical Society, Proceedings of the Society.
American Poultry Advocate, Syracuse, N. Y.
American Poultry Journal, Chicago, Ill.
American Sheep Breeder and Wool Grower, Chicago, Ill.
American Stock Farm, The, Winona, Minn.
American Stock Keeper, Boston, Mass.
American Sugar Industry and Beet Sugar Gazette, Chicago, Ill.
Breeder's Gazette, Chicago, Ill.
Boletim de Museu Goeldi, Para, Brazil.
Boletin Oficial de la Secretaria de Agricultura, Havana, Cuba.
Bulletins of the Botanical Department of Jamaica, and Reports of Public Gardens and Plantations.
Bulletins of the New York State Museum.
California Cultivator, Los Angeles, Cal.
Chicago Daily Drover's Journal, Chicago, Ill.
Colman's Rural World, St. Louis, Mo.

Connecticut Farmer, New Haven, Conn.
Cotton Seed, The, Atlanta, Ga.
Elgin Dairy Report, Elgin, Ill.
Evening Tribune, Providence, R. I.
Farm and Fireside, Springfield, Ohio.
Farm and Live Stock Journal, Detroit, Mich.
Farm Journal, Philadelphia, Pa.
Farm Life, Chicago, Ill.
Farm Poultry, Boston, Mass.
Farm, Stock and Home, Minneapolis, Minn.
Farmers' Advocate, London, Ontario.
Farmers' Guide, Huntington, Ind.
Farmers' Review, The, Chicago, Ill.
Feather, The, Washington, D. C.
Feathered World, The London, England.
Flour and Feed, Waukegan, Ill.
Fruit Grower, The, St. Joseph, Mo.
Geflügel-Züchter, Hamburg, Wis.
Hoard's Dairyman, Fort Atkinson, Wis.
Holstein-Fresian Register, Brattleboro, Vt.
Homestead, The, Des Moines, Iowa.
Hospodárské Listy, Chicago, Ill.
Indiana Farmer, Indianapolis, Ind.
Journal Royal Horticultural Society, London, England.
Kansas Farmer, Topeka, Kansas.
Kimball's Dairy Farm, Waterloo, Iowa.
Maryland Agricultural Quarterly, College Park, Md.
Massachusetts Ploughman, Boston, Mass.
Metropolitan and Rural Home, The, New York City.
Michigan Farmer, The, Detroit, Mich.
Miscellaneous Publications, Department of Agriculture and Mines, Natal, Africa.
Modern Farmer and Busy Bee, The, St. Joseph, Mo.
Missouri Agricultural College Farmer, Columbia, Mo.

National Stockman and Farmer, Pittsburg, Pa.
Nebraska Farmer, Omaha, Neb.
New England Farmer, Brattleboro, Vt.
New England Homestead, Springfield, Mass.
New Farm, Preston, Md.
New Zealand Dairyman, The, Wellington, N. Z.
New Hampshire Farmer and Weekly Union, Manchester, N. H.
Northwest Horticulturist, Tacoma, and Seattle, Wash.
Nut Grower, The, Poulan, Ga.
Ohio Farmer, Cleveland, Ohio.
Oregon Agriculturist, Portland, Oregon.
Orff's Farm and Poultry Review, St. Louis, Mo.
Pacific Dairy Review, San Francisco, Cal.
Poultry, Peotone, Ill.
Poultry Gazette, Kansas City, Kans.
Poultry Herald, St. Paul, Minn.
Poultry Husbandry, Waterville, N. Y.
Poultry Keeper, Quincy, Ills.
Poultry Standard, Stamford, Conn.
Poultry Success, Des Moines, Iowa.
Poultry Topics, Lincoln, Neb.
Practical Farmer, The, Philadelphia, Pa.
Practical Fruit Grower, Springfield, Mo.
Prairie Farmer, The, Chicago, Ill.
Publications of the Department of Agriculture, Ontario, Canada.
Publications of the Florida Department of Agriculture.
Publications of the Department of Agriculture, Mysore State, India.
Publications of the Imperial Agricultural Experiment Station, Nishigahara, Tokyo, Japan.
Publications of the Maine State Board of Agriculture.
Publications of the Massachusetts State Board of Agriculture.
Publications of the Department of Agriculture, New Zealand.
Publications of the North Carolina State Board of Agriculture.
Publications of the Ohio State Board of Agriculture.

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OF THE

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FOR THE

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Publications of the Department of Agriculture, University College, North Wales.
Publications of the Pennsylvania Department of Agriculture.
Publications of the Rhode Island State Board of Agriculture.
Publications of the Department of Agriculture, Victoria.
Publications of the Virginia Department of Agriculture.
Publications of the Department of Agriculture of Western Australia.
Queensland Agricultural Journal, Australia.
Reliable Poultry Journal, Quincy, Ill.
Republic, The, St. Louis, Mo.
Rock Products, Louisville, Ky.
Rural New-Yorker, New York City.
Rural World, London, England.
Skandinavisk Farmer Journal, Minneapolis, Minn.
Southern Fancier, Atlanta, Ga.
Southern Farm Magazine, Baltimore, Md.
Southern Planter, Richmond, Va.
Successful Farming, Des Moines, Iowa.
Successful Poultry Journal, Chicago, Ill.
Sugar Beet, The, Philadelphia, Pa.
Sec. da Agr. Estado de Sao Paulo, Boletim da Agriculture.
Texas Farmer, Dallas, Tex.
Town and Country Journal, San Francisco, Cal.
Up-to-Date Farming and Gardening, Indianapolis, Ind.
Wallace's Farmer, Des Moines, Iowa.
Western Fruit Grower, St. Joseph, Mo.
W. Weddel & Co's. Colonial Dairy Produce Report, London, Eng.
West Virginia Farm Review, Charleston, W. Va.
Wilson Bulletins, Wilson Ornithological Club, Oberlin, Ohio.
Wisconsin Agriculturist, Racine, Wis.
Year Book, and current publications of the Deutschen Landwirtschafts-Gesellschaft.

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AND

ANNUAL REPORT

OF THE

RHODE ISLAND AGRICULTURAL EXPERIMENT STATION,

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PROVIDENCE:
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